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THE UNIVERSITY OF ALBERTA

RESPONSE OF WILD UNGULATES TO LOGGING PRACTICES IN ALBERTA

by

HERBERT O. TOMM

A THESIS

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To my wife, Dianne, and my son, Mathew, whose continued moral support and confidence I deeply appreciate. Special apologies to Mathew for "daddy go to office again".

ABSTRACT

Impact assessment of the effects of logging practices on wild ungulates was conducted in the west-central forests of Alberta during the summer of 1976. Ungulate species studied were moose (*Alces alces*), deer (*Odocoileus virginianus* and *O. hemionus*), and elk (*Cervus canadensis*).

Utilization of clearcut and partial cut blocks was the dependent variable evaluated. Total cutblock use and utilization trends over distance from cover on cutblocks were determined by pellet group counts and shrub utilization measurements.

Analysis of variance was conducted to test the independent variables of geographic region, the effect of harassment, distance from cover and ungulate species. Results indicated that distance from cover was a significant factor affecting the utilization of clearcut blocks by ungulates. However, there was a significant difference by species in distance from cover use trends. Moose utilization was consistently more uniform over cutblocks compared to deer and elk use. The latter two species displayed a preference for cutblock edges. There was also a significant difference by ungulate species in response to harassment. Total cutblock use by moose was appreciably lower in high harassment cutblocks. The effect of harassment on total cutblock use was not apparent for deer and elk.

Chi-square analysis also indicated that harassment exerted a significant effect on the pattern of cutblock utilization over distance from cover for moose. Again, the effect of harassment on distance from cover use trends for deer and elk was not apparent.

Distance from cover did not affect utilization patterns on partial cuts for moose and deer. However, elk use of partial cuts was minimal and confined to cutblock edges.

An extension of analysis of variance (multiple regression using dummy variables) was used to test for other significant factors affecting total cutblock use by moose and deer. Moose utilization was significantly correlated to cutblock size, the interspersion of cutblocks and harassment. For deer, the combination of block size, interspersion of cutblocks and site treatment was significant. Cutblock shape, or the extent of edge perimeter, was also significantly correlated to deer utilization of cutblocks.

Based on the results of this study, recommendations and guidelines are presented for the integrated management of timber and wild ungulates.

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CHAPTER I

PROBLEM DEFINITION

Introduction

Contemporary forest management is faced with a situation of escalating demand for the variety of forest outputs from a shrinking land base. Social criteria, as manifested by public awareness and concerns, are exerting an increasing influence on land management strategies, particularly in reference to resources lacking a definable economic status (Jeffrey *et al.* 1970, Rowe 1973).

In response to this demand, multiple use, or deliberate land management for two or more resources, is the stated land use objective in many public forests (Thompson *et al.* 1973). However, establishment of land use priorities for multiple use management is difficult where values attached to individual forest resources are not directly comparable (Madill 1973).

Timber and wildlife are two forest products that stand in discordant contrast in terms of perceived benefits to society. While many of the accrued benefits to the forest industry are measureable by economic criteria, no comparable satisfactory index exists for evaluating the wildlife resource (Thompson *et al.* 1973). Thus, integrated management often has been reduced to a state of dependence on the

incidental production of wildlife in primary-use timber-production areas.

The historical relationship of forest harvesting and abundance of large game animals does suggest a generalized compatibility and indicates the feasibility of integrated management. It is generally agreed that past logging activities have contributed to the present diversity and abundance of big game in North America (Lyon 1966, Pengelly 1963). With forestry practices supplanting wildfires as the major recurring determinant of vegetational heterogeneity (Lyon 1966), the potential for deliberate, simultaneous production of these forest outputs is greatly increased.

Despite this apparent compatibility, there remains an urgent need for assessment of the impact of forestry practices on wildlife. Demands on the wildlife resource are increasing. With the continued trend towards primary use timber exploitation, dependence on the incidental production of wildlife is no longer adequate (Stelfox 1972).

Present attempts at integration are limited by inadequate knowledge of trade-off relations among outputs of production functions (Thompson *et al.* 1973). The missing factor is the knowledge and techniques required to produce superior environments for animals (Lyon 1966). Guidelines for management are often based on derived, generalized trends of the ecologies of affected species, and are often neither site nor species specific (Hudson 1976). Such blanket guidelines do little in the way of positive

management and may in fact, constrain the scope and flexibility of timber management planning.

The Alberta Situation

Two-thirds of Alberta's land area is forested, encompassing approximately 160,000 square miles. With the exception of national and provincial parks, wilderness areas and other special areas, this 'Green Zone' is managed for timber production as a major use on a sustained yield basis (Patching 1977). The Alberta Forest Service has endorsed the concept of integrated use and provides operating guidelines in recognition of multiple forest values. Timber management planning and harvesting operating ground rules for wildlife criteria define and attempt to protect major habitat components. The application of these guidelines is designed for normal or average conditions. While Forest Officers "have the authority to waive or amend the application of these rules" (Henderson 1977, p. 3), local experience and quantitative data is often lacking. In the absence of such information, guidelines are often accepted as rules.

In reference to this situation, Steele (1973) noted that models for impact assessment do exist. However, the precision of assessments remains in doubt "simply because of inadequate knowledge of the effect of major disturbance on such things as water regime, game distribution, and vegetational recovery" (Steele 1973, p. 302).

It was the objective of the present study to determine and evaluate the important effects or pathways of forestry practices on the recreationally important big game species in Alberta; moose[1] (Alces alces andersoni Peterson), deer (Odocoileus virginianus ochrourus Bailey and O. h. hemionus (Rafinesque)), and elk (Cervus canadensis nelsoni Bailey). A secondary objective was to relate results to the status of timber harvesting in Alberta and formulate recommendations for operational integrated management.

General Model of Impact Assessment

Most generalizations relating the impact of forestry practices on wildlife have been based on the biophysical features of the altered habitat (Behrend 1972). Comprehensive assessment, however, requires definition of both the resource base and response mechanisms of affected wildlife species.

The term habitat can be referred to as an animal's operational environment (Hudson 1975). Within this habitat, the fundamental needs of wildlife for food and cover must be fulfilled. Generally, each species displays a characteristic set of preferences in habitat selection. These preferences are expressed in the concept of range balance, which prescribes the composition of environmental types furnishing

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[1] Source of scientific nomenclature: Soper, J.D. 1964. The mammals of Alberta. Queen's Printer, Edmonton, Alta. 402 pp.

food, cover and other habitat requirements (Leopold 1948). Habitat alteration via logging practices essentially determines the constituent types of range balance.

Habitat use behavior, in turn, determines the degree of range utilization. While the strategy of habitat use is largely dependent on energy budget considerations, it also reflects requirements for expression of social behavior and security (Hudson 1975).

For sedentary species of ungulates, habitat use behavior is often characterized by a strong home range tendancy, the size of which is restricted by a 'cruising radius'. With respect to logging practices, this behavioral adaptation determines how effective the various sizes and interspersion of cutblocks are in providing forage and cover requirements (Telfer 1974).

With the increasing scale of logging operations, security requirements become more critical. Response or adjustment to harassment may take precedence over other considerations in habitat selection. As Cowan (1974, p. 292) noted, full utilization of game range can only occur in a "known and predictable social and physical environment".

The proportion of total range that is available and utilized is therefore determined by a combination of factors affecting the habitat use strategies of ungulates, including adjustment to harassment factors. Habitat occupancy patterns in logged areas also may be altered by the impcsition of barriers and corridors (Hudson 1976, Pengelley 1963).

Problem Statements

A hypothesized model of the major pathways and consequences of forestry practices on wild ungulates is presented in Figure 1. Based on this perspective, problem statements for the study were formulated.

What are the effects of habitat alteration on game range, and subsequent utilization patterns of wild ungulates? How do barriers and corridors affect ungulate distribution and habitat accessibilty? How does harassment affect distribution patterns of wild ungulates, and what are the effects on behavior and activity with regard to cutblock utilization? Do responses differ for moose, deer and elk?

Discussion of Variables

With respect to ungulate utilization of logged areas, two dependent variables were recognized; utilization over distance from cover and total cutblock use. Utilization over distance from cover reflects patterns of use and indicates completeness of habitat use. Total cutblock utilization defines overall response to cutblock parameters and characteristics. Definition of independent variables was made in reference to these indices.

Habitat Alteration

Modifications in landscape heterogeneity through

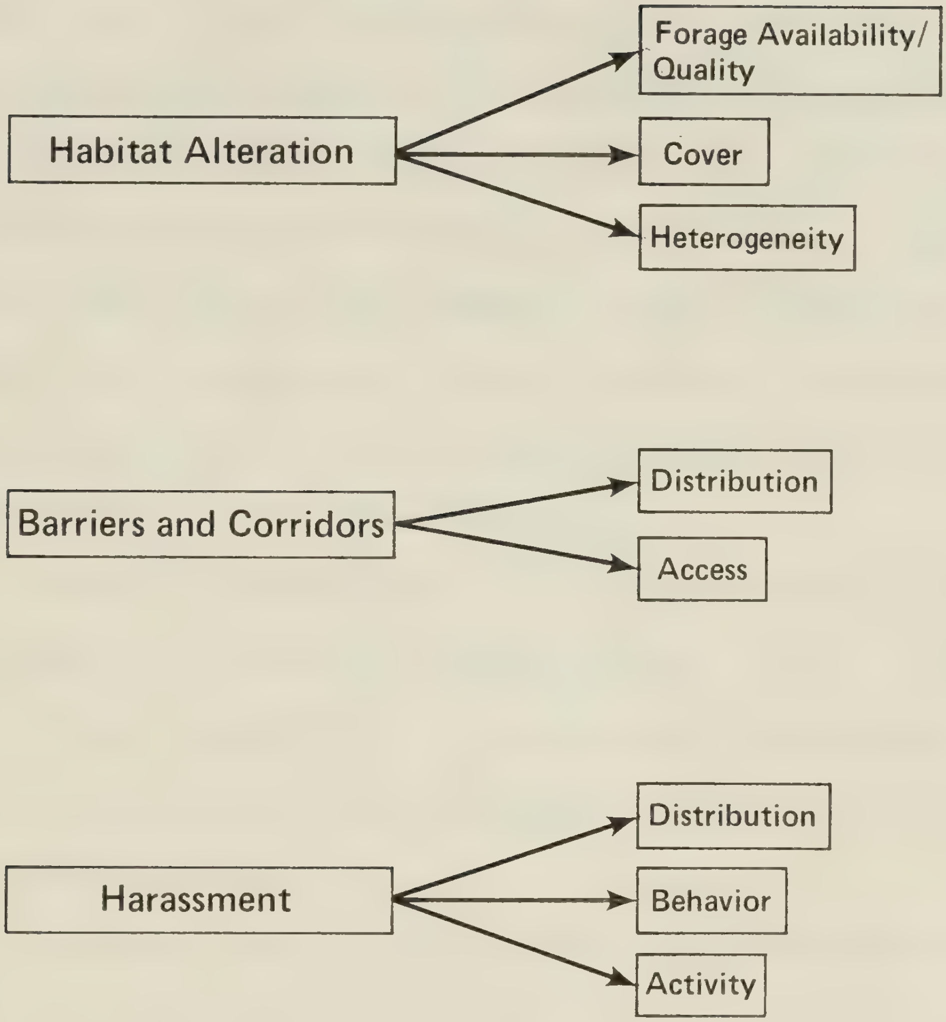

Figure 1: Pathways and consequences of timber harvesting

habitat alteration affect the game range components of food and cover, and their interspersion. Successional retrogression initiated by the removal of the overstory canopy has the general effect of increasing available forage biomass and plant diversity. Rate and amount of forage production is related to the temporal stage of vegetational recovery following logging, local site conditions, and type and degree of soil disturbance (Taber 1973). Slash burning and scarification, for example, favour pioneering herbaceous species and initially retard shrubby vegetation (Hooven 1973, Stelfox and Cormack 1962). Burning also may enhance forage palatability (Taber 1973).

Forage production is also related inversely to overstory crown density (Young *et al.* 1967). Partial cuts are seldom effective in stimulating production where less than 50 percent of the dominant canopy cover is removed (Gill 1957b).

Abundance and productivity of preferred forage plants may be an important determinant of the intensity of habitat use, and ultimately, may limit the potential carrying-capacity of game range. Impact assessment based on this index does have validity where ungulate populations are limited primarily by food (Hudson 1976).

Cover, as it relates to game requirements, can be categorized as thermal cover, and cover for provision of security (Black *et al.* 1976). The winter and early spring season is considered the critical period on which practical

wildlife management should be based (Leopold 1948). Thermal cover is required to minimize energy expenditure caused by temperature extremes, and to facilitate locomotion in deep snow. The interspersion of forage and cover areas may impose a critical constraint on habitat use in winter, particularly for white-tailed deer (Gill 1957a). Snow conditions also present a definite barrier to utilization of cutover lands (Kelsall and Prescott 1971, Telfer 1970).

Despite the critical aspect and constraints imposed by climatic paramters, the overall impact of forestry practices on winter habitat is not that severe. The proportion of winter range to total range is relatively small; estimates vary from 5 to 15 percent (Gill 1957a, Telfer 1970). While these areas can be identified and afforded protection, it is inevitable that the expanded summer ranges of ungulates coincide with logging operations (Lyon 1966). Recent studies have also suggested that the importance of summer ranges to population viability has been underestimated (Julander et al. 1961, McCaffery and Creed 1969). The present study therefore did not differentiate game range on a seasonal basis.

Security cover is required for full utilization of forage-producing habitat, even in the absence of human activity or predators (Black et al. 1976). On large scale clearcuts, skewed utilization patterns are the result of foraging areas too far from adjacent cover (Dealy 1975, Stelfox and Cormack 1962). Response curves of high

peripheral use are typical, although variations are evident by species.

Cover as an ingredient of range balance is often the critical determinant of the impact of timber harvesting. Moose, deer and elk are considered 'edge' species, requiring a dispersion of seral vegetation types (Hudson 1975). Where forage-producing habitats are limited, logging has a highly beneficial effect in enhancing the productivity of game range. Further cutting where an ideal range balance already exists, however, would reduce range carrying-capacity and the subsequent ability of populations to exploit logged areas (Patton 1976, Stelfox 1972).

Ideal range balance varies by the habitat use behavior of the ungulate species considered, and is generally characterized by home range size. Deer, with a comparably smaller home range, are favoured by well-dispersed patterns of small-size patch cuttings (Telfer 1974). Moose are more flexible in cover requirements and range may be balanced with larger clearcuts (Peek et al. 1976, Telfer 1974). Ideal range balance for elk includes relatively large foraging areas to accommodate the feeding behavior and gregarious social organization of the species (Black et al. 1976, Stevens 1974).

Utilization of cutblocks is also a function of individual cutblock heterogeneity, as well as overall landscape diversity. Contributing variables to the former include size of cut, shape of cut and topographical

variation (Harper 1971, Telfer 1974).

With respect to logged units, shape of cut essentially determines contribution to habitat edge. For cutblocks of comparable size, a greater edge perimeter generally indicates superior habitat for ungulate species dependent upon range diversity (Leopold 1948, Telfer 1974).

Size of blocks also contributes directly to edge effect. On an edge per unit area basis, many smaller cuts contribute more habitat edge versus a few large cutblocks. Taber (1973) also hypothesized that size of cut is an important determinant of intensity of use by virtue of strong home-range utilization tendancies. Assuming the same number of animals are attracted to cutblocks of different sizes, smaller cutting units would be utilized to a greater extent on a per unit area basis.

Topographical variation has the general effect of increasing habitat diversity and subsequent suitability as game range (Stelfox and Taber 1969). Terrain variability could also add to the security of foraging animals by reducing visual line-of-sight distances (Dealy 1975, Lyon 1975).

Barriers and Corridors

The general consequences of this pathway are to funnel, deflect or shortstop animal movement (Hudson 1976). In scale and extent, logging roads are a major source of such

features. Impact of roads as barriers and corridors on non-migratory ungulates is, however, not that great. Deer, for example, are adaptable to the extent of utilizing such features as travel lanes and foraging sites (Carbaugh et al. 1975). An important associated consequence of logging roads is related to harassment effects via increased vehicular access and hunting (Stelfox 1972).

On-site utilization of cutblocks can be limited by logging slash acting as a physical barrier (Garrison and Smith 1974). In terms of forestry practices, an indication of potential accessibility is provided by site treatment. Silvicultural techniques such as slash burning and scarification reduce the volume of slash and provide corridors for cutblock access (Walker et al. 1971).

Harassment

Harassment involves the exposure of animals to new and usually alarming stimuli (Hudson 1976). The consequences are many, and include altered behavioral patterns and displacement of animals (Stelfox and Taber 1969). With respect to utilization of logged areas, harassment can affect both total cutblock use, as well as completeness of use (Dealy 1975).

Differences in response patterns of ungulate species to harassment can be related to aspects of behavior. Cowan (1974) described elements of behavior as either fixed and

automatic, or generalized responses to stimuli that are changeable and adaptable. Although the behavioral repertoire of ungulates contain elements of both categories, it is the latter category that is more effective in dealing with harassment since it allows for adjustment to new situations (Cowan 1974, Hudson 1975).

Deer display the plasticity in behavior that permit learned and adaptable responses. Regularly occurring harassment stimuli, for example, have little effect on activity patterns after behavioral adjustment (Carbaugh _et al._ 1975, Dorrance _et al._ 1975). Irregular stimuli, or harassment associated with hunting, does, however, disrupt range occupancy patterns and affects flight behavior to some degree (Dorrance _et al._ 1975, Hood and Inglis 1974).

Response mechanisms of moose to environmental stimuli appear to be relatively fixed or automatic, and lack the degree of behavioral plasticity expressed by deer (Prescott 1974). Although there is little information on moose behavioral responses to forestry practices, the species does display a high threshold to such disturbances as flying aircraft (Renewable Resources Consulting Ltd. 1974). Similarly, hunting pressures invoke little behavioral adjustment. Goddard (1970), for example, reported that emigration of animals was not evident from heavily hunted areas.

Elk tend to deal with harassment by avoidance mechanisms. Lyon (1975), for example, noted 2 miles of

undisturbed timber or a topographic barrier was required to achieve security from logging activity. Ward (1973) also observed similar avoidance reactions from highway traffic and recreational facilities, although security was achieved at lesser distances than reported for the above study. Cover appears to be a requirement for elk in dealing with harassment (Black et al. 1976, Lyon 1975).

Study Hypotheses

The hypotheses formulated were tested against the null hypothesis which states no relationship exists between dependent and independent variable(s). The following relationships were proposed for study purposes:

1. No relationship exists between harassment and total cutblock utilization for combined ungulate use
2. Distance from cover does not affect cutblock utilization trends for combined ungulate use
3. The effect of harassment and distance from cover on cutblock utilization for combined ungulate use is not different by geographic region
4. Harassment does not influence trends of cutblock utilization over distance from cover for combined ungulate use
5. The effect of harassment on total cutblock use does not differ for moose, deer and elk
6. Utilization trends over distance from cover do not differ for moose, deer and elk
7. Harassment does not affect trends of cutblock utilization over distance from cover for ungulate species considered individually

8. Utilization of cutblocks by distance from cover does not deviate from even or uniform use on partial cuts where security cover is available

9. No relationships exist between independent variables and total cutblock use for moose, deer and elk. The predictor variable list includes site treatment, forage quantity, cover, years after logging, harassment and habitat diversity indices (cutblock dispersion, size and shape, and topography)

CHAPTER II

METHODS

Description of Study Area

To obtain extensive biogeographical representation, three general areas for study were chosen. These areas corresponded to Alberta Forest Service administrative forests, and included Whitecourt, Grande Prairie and Rocky-Clearwater. Further definition of the study area was made on the basis of timber management units and licences (Figure 2). Geographically, these areas lie to the south and west of the Province, and from a land management perspective, have been subjected to a multiplicity of uses (Table 1). The scope of land use practices provided the opportunity to assess the effect of harassment on cutblock utilization patterns of big game animals.

The forested areas managed for timber in Alberta fall in two forest zones: Boreal and Subalpine (Rowe 1972). The Boreal Forest zone encompasses the bulk of this land area, with the Subalpine zone represented by a narrow belt parallel to the Rocky Mountains in the southern one-half of the Province. Within the Boreal Forest, three sections are found in the study area: mixedwood, lower foothills and upper foothills (Table 2).

As the name implies, the mixedwood section is

Figure 2: Map of study area depicting administrative forest and management units sampled.

Forest	Area (sq. miles)	Features
Grande Prairie	14,075	-pulp industry -timber production -gas, sulphur and oil extraction
Rocky-Clearwater	6,837	-hydoelectric installations -extensive tourist travel -gas, coal and sulphur extraction -timber and watershed management
Whitecourt	7,824	-oil and gas extraction -coal exploration -timber production -tourists -big game hunting

Table 1: Resource development features. Source: Alberta Forest Service information files

Forest	Management Unit	Licence	Forest Zone or Section
Grande Prairie	G5	S11	lower foothills
		S12	lower foothills
	G7	L1A	lower foothills
Rocky-Clearwater	R2	L14	transition from upper foothills to subalpine
	R4	L20	lower foothills
	R6	L12	transition from upper foothills to subalpine
	R9	L3	subalpine
		L18	upper foothills
		L26	upper foothills
Whitecourt	W2	L41	lower foothills
	W3	L6	mixedwood and transition to lower foothills

Table 2: Biogeographical overview of the study area. Source: Rowe, J.S. 1972. Forest regions of Canada. Dep. of Environ., Can. For. Serv. Publ. No. 1300. 172 pp.

characterized by a mixed assemblage of tree species,[1] including trembling aspen, balsam poplar, white birch, white spruce and balsam fir. Deciduous species tend to predominate in earlier successional stages. Pine is found on drier sites with tamarack and black spruce occupying mesic sites. Relief tends to be moderate, except in transitional areas. Soil development is characteristically to gray luvisols.

The transition from mixedwood to lower foothills is characterized by an increase in altitude. Accompanying tree species transition is to lodgepole pine, along with trembling aspen and balsam poplar. This association is dominant on sites disturbed by fire. Climax stands include white and black spruce, and to a lesser extent, balsam and alpine fir. White birch, on well-drained sites, and tamarack, on poorly-drained sites, have local importance. The topography tends to be rolling, with interspersed plateaus. Soils on upland sites are gray luvisols and related podzols.

The upper foothills continue the transition from Boreal to Subalpine, and form a narrow belt parallel to the Subalpine Forest zone. Tree associations are characterized by an absence of deciduous species with conifers, notably lodgepole pine and white spruce, predominating. Black spruce, common to the north, alpine fir and scattered

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[1] Scientific names of trees and shrubs referred to in this report are listed in Appendix 1.

tamarack are associated species. Topography of the upper foothills is characterized by deep valleys and high rounded hills.

The Subalpine Forest zone is the mountainous counterpart to the Boreal Forest and occupies a narrow range on the east slopes of the Rockies. This zone is characterized by a coniferous association of Englemann and white spruce with lodgepole pine occupying burned areas and drier sites. At higher elevations, alpine fir becomes more common, along with whitebark pine and alpine larch. Topography is typically mountainous with deep valleys and steep slopes. The lack of soil development is reflected by thin, undifferentiated profiles over bedrock.

From a geoclimatic perspective, most of Alberta is characterized by a Western Plains physiography and a Cool Temperate Climatic zone. To the southwest of the Province, the Western Cordillera occurs, accompanied by a transition to a Polar Climatic zone. A summary of major geoclimatic features by forest is presented in Table 3.

Timber Harvesting Systems

Timber harvesting in Alberta is generally conducted by a clearcutting system to produce even-aged, second-growth stands. A 'checkerboard' pattern of cut and uncut stands is typically produced, although constrained by topography. Block sizes are variable, but average less than 30 acres for

Forest	Physiography and Altitude (MSL)	Soils	Temperature Range and Precipitation (mean annual)
Grande Prairie			
	Western Cordillera to the west; Alberta Interior Plains including Alberta High Plains; altitude 1,000-8,000'	gray luvisols or related podzols, some solonetzic	45-55°F 14-22"
Rocky-Clearwater			
	Western Cordillera; some areas in Alberta High Plains; altitude 3,000-8,000'	undifferentiated complexes, shallow humo ferric podzols, eutric and dystric brunisols; gray luvisols at lower elevations	45-60°F 18-22"
Whitecourt			
	Alberta Interior Plains including Alberta High Plains; altitude 1,000-6,000'	gray luvisols	50-60°F 18-24"+

Table 3: Geoclimatic overview of the study area. Source: Patching, D.E. 1977. Terms of reference and background information. Alta. Environ. Cons. Auth., Public Hearings on the Environmental Effects of Forestry Operations in Alberta, Info. Bull. No. 1. 37 pp.

sawlog operations (Beck 1978). A trend to larger block sizes is general with more recent cuts.

While the study concentrated on clearcuts, timber operations producing partial cut effects have local importance. These areas have been the result of salvage operations and older diameter-limit cuts. In addition, some clearcutting operations also produce partial cut characteristics, particularly where a large hardwood component is left as residual cover after logging (DePape and Collins 1977).

Selection of Sample Cutblocks

Selection of clearcut units for study was essentially determined by a stratified random method. Timber management units, considered representative for each forest, were chosen on the basis of distribution of cutblock sizes and ages. Timber licences were subsequently delineated as the more specific study areas. Selection criteria included accessibility to the area, availability of maps, cutblock characteristics and contrasts in harassment factors. All cutblocks in a given licence were considered of the same harassment category prior to sampling.

Individual cutblocks were selected in a random manner within broadly defined limits. These limits outlined the scope of the experiment and defined the range in measurements of variables evaluated.

With respect to years after logging, a range of 2 to 9 years was accepted. This period includes the onset and continuation of increased forage production and limited cover values (Stelfox et al. 1976). Similarly, a size range of 5 to 120 acres was defined, based on an initial survey of the study area. Atypical clearcut features, such as residual cover and excessive logging debris and/or blowdown, resulted in sample rejection. A residual crown cover of up to 10 percent, subjectively appraised for individual blocks, was accepted. The purpose of randomness in selection was then to 'average out' the effect of block sizes, ages and other parameters.

Selection of partial cuts was limited by availability. Larger cutblock sizes and older cuts were therefore accepted (Table 4). Although contrasts in harassment were not apparent, the partial cuts did afford the opportunity to assess the influence of residual cover on ungulate utilization patterns. A residual cover of 15 to 25 percent, consisting of trees and tall shrubs (8.0+ ft.) was characteristic of the partial cuts in the study area.

Sampling Design

Total cutblock use and trends in utilization were assessed by pellet group surveys. Supportive utilization information was also obtained by shrub utilization checks.

Management Unit and Licence	Block No.(s)	Legal Description	Years Cut	Area Sampled (acres)
G5 S12	11, 15-17, 20-23	Twp. 64, Rge. 25, W5M	1969-70	273
G7 L1A	39,V,V1	Twp. 62, Rge. 5, W6M	1960-62	299
R9 L3	1	Twp. 34, Rge. 12, W5M	1966-69	694

Table 4: Description of partial cuts

Pellet groups have proved useful both as a census technique and for indicating trends in habitat use (Neff 1968). Pellet group counts are particularly useful for the latter purpose in that a 'fixed' kind of evidence allows for spatial comparisons of habitat use trends that can be subjected to statistical analysis (Neff 1968). The technique is based on the premise that a pellet group count is indicative of the time an animal spends in that habitat (Bennett et al. 1940). However, it should be recognized that "the relationship of defecation to other animal activities remains conjectural" (Neff 1968, p. 612). Shrub utilization surveys were therefore conducted to verify the relationship of pellet group distribution to habitat preference.

Trends in utilization were determined in relation to distance from adjacent cover. Cutblocks were therefore

envisioned as consisting of 'subhabitats' relating to the concentric areas at successive distances from cover. Distance intervals were established at 1 chain,[1] beginning at 1 chain inside cover.

Because of the suspected non-random dispersion of pellet groups on cutblocks, a systematic survey system was adopted for field sampling (Bowden et al. 1969, McConnell and Smith 1970). The systematic design provided the desired general sampling coverage and indicated differences in ungulate use by subhabitats or distances from cover.

Sampling intensity was essentially dictated by time and cost factors. The field objective was to sample one cutblock per man-day. The design adapted for the study is diagramed in Figure 3.

Starting point of a survey was randomly selected within 4 chains of a defined tie point. Tie points were generally recognizable features on maps or aerial photographs such as cutblock corners, or road and cutblock edge intersections. Transect lines were oriented to maximize within-line variability, for example, topography, and minimize between-line variation (Neff 1968). Pellet group plots were then spaced 2 chains on transect lines. Because shrub utilization data were intended as supportive information, sampling intensity was reduced and plots placed at 4-chain intervals on transect lines.

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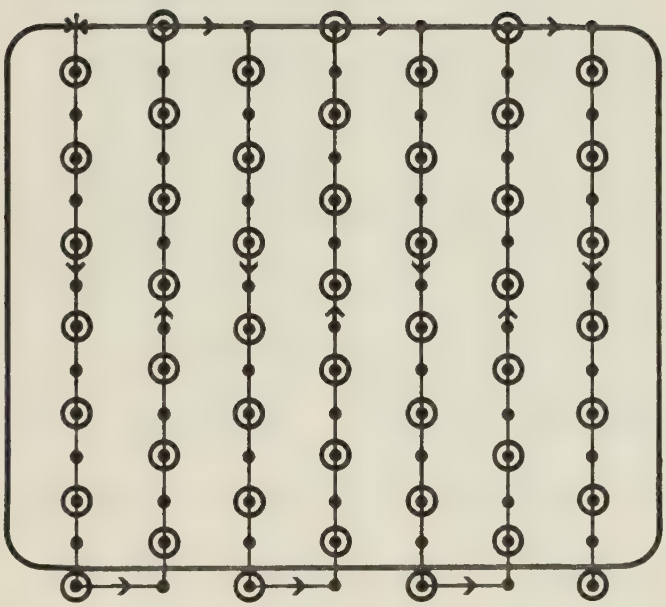
[1] One chain is equal to 66 feet.

Cutblock



Design Specifications

Transects: 4 chains apart

Pellet group plots: 2 chains apart

Range plots: 4 chains apart

Plot sizes:

Pellet group plots
circular r = 11.78 feet
area = .01 acres

Range plots
circular r = 5.64 feet
area = 100 square feet

Legend:

• pellet group plots

O range plots

→ direction of transects

* tie point (starting point)

Figure 3: Cutblock sampling design and specifications

Plot shape was circular for ease in location of boundaries. Initially, a plot radius of 5.64 feet was designated for both range and pellet group plots. Subsequently, the pellet group plot radius was increased to 11.78 feet because of low counts. Larger plot sizes or increased number of plots tend to reduce skewness resulting from low enumerations (Neff 1968).

The sample design yielded an average sampling intensity of 1.2 percent and .13 percent for pellet and range surveys, respectively. Although all subhabitats were sampled at equal intensity, the number of plots generally decreased at greater distances from cover due to corresponding smaller areas. However, subsequent clumping of distance categories for analysis purposes tended to equalize plot numbers.

Sampling intensity on partial cuts was comparatively less because of the large, relatively homogeneous blocks. Transects were established at 10-chain intervals, with plots located as previously described. Resulting sampling coverage was .67 percent and .076 percent for range and pellet group plots, respectively.

Measurement of Variables

For discussion purposes, measurements of variables are presented by description of cutblock parameters, utilization assessment and cutblock harassment classification.

Cutblock Parameters

Sketch maps of cutblocks, obtained by pacing of transects, provided information on block size and length of edge perimeter. From these measurements, an index of habitat edge was calculated which standardized the extent of cutblock edge perimeter on a per unit area basis (chains of edge perimeter per acre).

Empirical descriptions of cutblocks included site treatment, topography and cover types of adjacent stands. Description of topography followed the class designations of the Canadian system of soil classification. Cover type definition adhered to the Alberta Forest Service type mapping scheme and included species, density and height of trees. Year of cut and site treatment information was obtained from Alberta Forest Service files.

An index for describing the interspersion of cutblocks, as related to ungulate habitat use behavior, was based on the assumption that only cutblocks within home range territory will affect animals (Taber 1973).

Calculation of block dispersion indices was further based on the following assumptions and standards:

1. A cruising radius of 40 chains (.5 miles) was designated as the common denominator of home range size for moose, deer and elk (Houston 1974, Taber 1973)

2. Forest openings (or cutblocks) at or greater than 40 chains distance from a cutblock were considered to have a negligible effect on ungulate utilization patterns on that cutblock. The 40-chain distance was

therefore set as the maximum allowable distance per forest opening in index calculation

3. A standard of 4 forest openings was used for block dispersion calculation. This figure was generally representative of the average number of openings within a 40-chain radius of any given cutblock in the study area. If more than 4 openings were located within the above radial distance, only the nearest 4 were measured

The block dispersion index for a cutblock was then determined by summing the linear distances to the nearest 4 forest openings, up to a maximum of 40 chains per opening and 160 in total. For example, a cutblock with the nearest neighboring cutblocks 10, 30, 50 and 100 chains in distance would be assigned an index value of 120. Because of the maximum allowed distance of 40 chains, an index of 120 is also equivalent to 4 openings spaced at an average distance of 30 chains from a cutblock. By comparison, a block dispersion index of 20 would indicate that the average distance to the next 4 forest openings from a cutblock is only 5 chains.

Utilization

Cutblock utilization patterns were determined by shrub browsing assessment and pellet group counts. Ungulate species were not differentiated in the former survey. Moose, deer and elk were identified by pellet groups, although distinction between white-tailed and mule deer was not made. Identification of deer species by pellet groups is difficult

without knowledge of local distributions of these species. For purposes of this study, the response of both species to altered environments was considered similar.

All pellet groups found in a plot were tallied, with plots identified by numerical designation, distance (to nearest chain) and azimuth to cover, and location on the sketch map. Pellet groups were considered 'in' if midpoints fell inside plot boundaries. However, groups were not defined by a minimum number of individual pellets. Two searches, clockwise and counter-clockwise, were generally made to reduce observer bias.

Shrub utilization survey methodology was adapted from procedures reported by Aldous (1944) and Dasmann (1948). Information recorded for shrub species included height and height range, density, and degree of browsing. Available browse was considered to include shrubs up to 8 feet in height (Telfer and Scotter 1975). Density, or ground coverage, of forbs and grasses also was recorded.

Shrub density was recorded by the number of square feet completely covering the ground surface for that species. On a plot size of 100 square feet, this figure was directly equivalent to percent. Degree of browsing was recorded by percent categories of nil (0), low (up to 10), moderate (11-50), and high (50+). Stickney (1966) reported this procedure provided a good correlation to actual twig utilization on a weight basis for browsing pressures of up to 55-60 percent.

For purposes of the study, twig definition was adapted

from Telfer (1969 p. 917); "that part of a branch distal to the point where branch diameter would, if air dried, equal the largest observed for a stub of a browsed branch of that species". By this definition, twigs could contain several years growth. Variability in browse diameter utilization by different ungulates was also taken into account.

Harassment

From the literature review on this subject, several generalized trends in ungulate response were surmized. Regular predictable disturbances are less adverse, except when associated with hunting pressure. It is the irregular, novel and alarming stimuli that are more disruptive in terms of habitat occupational patterns.

While species responses can also be broadly defined, the basic problem in assessment is the questionable correlation between animal perception and response, and harassment assessment criteria. For this reason, differences in individual species response were not considered in formulating classification criteria.

Two limitations were encountered in defining the impact of harassment for classification purposes: (1) the degree of influence and relative importance of individual disturbance sources was generally unknown, and (2) the extent that visual and auditory barriers mitigate the impact of harassment was also generally unknown. These limitations, in

effect, prevented objective definition of harassment classes.

Cutblocks were therefore subjectively ranked in order from the least harassed cutblock to the most harassed block based on the following general criteria:

1. The known effects of harassment
    a) that irregular disturbances are more severe
    b) that regular disturbances are not as adverse, except when associated with hunting

2. Mitigating cutblock characteristics
    a) that reduce cutblock exposure (visual line-of-sight distance)
    b) that reduce visual and auditory proximity to disturbance sources

Ranked cutblocks were then equally divided into 4 categories, and common characteristics and features defined for each class. Assigned cutblock harassment designations were then readjusted based on classification criteria and common characteristics attributed to each class. The purpose of readjustment was to standardize, as far as possible, common characteristics of each class. Subsequent interpretation of analysis results could then be made on the basis of class characteristics and the positive or negative responses of moose, deer and elk to designated harassment classes. Description of harassment categories is given in Table 5, and designation of harassment classification for cutblocks listed in Appendix 2.

Harassment Category: HIGH		
	Criteria:	-auditory and visual proximity to disturbance sources
	Features:	-exposed to sights and sounds of high, generally regular, disturbance -disturbance factors lower, but more irregular, or higher exposure to disturbances
	Characteristics:	-good access to cutblock -high cutblock visibility (visual line-of-sight distances)
	Common sources:	-dry weather or all weather road through cutblock -high and regular vehicular traffic, for example, commercial traffic -lower, more irregular traffic, for example, weekend recreation traffic -associated hunting pressure with high accessibility -oil battery sites on cutblock -proximity to active logging -proximity to forestry camps and recreational sites
Harassment Category: MODERATELY HIGH		
	Criteria:	-same as above, except impact of disturbance reduced by features of this class
	Features:	-disturbance impact reduced by increased visual isolation, or -source of disturbance not severe enough to qualify for above
	Characteristics:	-visual line-of-sight reduced by residual cover or terrain -buffer strips along roads -off-road access to cutblock by truck trail or walk-in (minimum 3 chains)

Table 5: Harassment classification: criteria and description

Harassment Category: LOW		
	Criteria:	-visual and auditory isolation from disturbance sources
	Features:	-isolated cutblocks -disturbances, if present, minimal and mitigated by low cutblock exposure
	Characteristics:	-access by truck trail (4+ miles) or walk-in proposition (.5+ miles) -access to management unit poor, for example, truck trail or dry-weather roads, or long distance from population centres
	Sources:	-diverse recreational activities, for example, hiking -active logging, if present, screened by 2+ miles
Harassment Category: MODERATELY LOW		
	Criteria:	-same criteria as above, except harassment impact increased by class features
	Features:	-increased cutblock visibility, and/or -irregular, more alarming harassment sources
	Sources:	-low-incidence ATV recreational traffic

Table 5(cont): Harassment classification; criteria and description

Outline of Analysis of Data Procedures

Analysis procedures were based on field sampling methods, and designed to test for the hypotheses formulated. Three analysis techniques were employed; analysis of variance, chi-square analysis and multiple regression using dummy variables. Specific hypotheses were tested under each type of analysis. Where applicable, analyses were conducted for both shrub utilization and pellet group data.

Analysis of variance (factorial design) was used to test hypotheses of ungulate utilization on clearcuts, and included all or combinations of the following variables: geographic regions, harassment, distance from cover and ungulate species. The basic form of the analysis of variance table was, with some variation, set up as illustrated below. Associated hypotheses tested for the main effects and interactions are also indicated.

1. Regions
   -no hypothesis tested

2. Harassment
   -no relationship exists between harassment and total cutblock use for combined ungulate use

3. Distance from cover
   -distance from cover does not affect cutblock utilization trends for combined ungulate use

4. Species
   -no hypothesis tested

5. Regions x Harassment
   -the effect of harassment on total cutblock utilization for combined ungulate use is not different by geographic region

6. Regions x Distance from cover
   -the effect of distance from cover on cutblock utilization trends for combined ungulate use is not different by geographic region

7. Regions x Species
   -no hypothesis tested

8. Harassment x Distance from cover
   -harassment does not influence trends of cutblock utilization over distance from cover for combined ungulate use

9. Harassment x Species
   -the effect of harassment on total cutblock utilization does not differ for moose, deer and elk

10. Distance from cover x Species
   -utilization trends over distance from cover do not differ for moose, deer and elk

Analysis of variance could not test the hypothesis of no effect by harassment on distance from cover use trends for ungulate species considered individually. This hypothesis was therefore tested by chi-square analysis, where observed use over distance from cover for each harassment category was compared to a theoretical uniform (or expected) use curve.

Chi-square analysis was also used to test for hypothesis of even or uniform use on partial cuts where security cover was available. Analysis procedures were similar to the above, except that contrasts in harassment were not defined.

Multiple Classification Analysis (MCA), an extension of the analysis of variance technique (Andrews et al. 1973), was used to test for other significant factors affecting

total cutblock utilization. Prediction of cutblock utilization was then based on significant cutblock parameters, and expressed in the functional form of utilization = f(predictors a,b,c...).

CHAPTER III

RESULTS

Results are presented for analysis of variance of shrub utilization and pellet group data for clearcuts and partial cuts, respectively, and further MCA analysis of pellet group data. The final results section presents a summary of the range survey for browse species, determination of food preferences and contribution to diet for individual browse species.

Utilization Patterns on Clearcuts

The experimental design for analysis of utilization patterns was based on a factorial design without replication. Replication can be dispensed with when a large number of factors are involved in the analysis, and there is reason to believe interactions involving 3 or more factors are unimportant experimentally (Fisher 1966). The design enabled a large number of factor combinations to be tested simultaneously without enlarging the experiment. Higher order interactions were used as an estimate of error, where the apparent effects are assumed due principally to error.

The factorial design involves categorization of the dependent variable data base by each combination of independent variables (main effects). Because of the

limitations imposed by reduced plot representation at successive greater distances from cover, analysis of variance was conducted by two different schemes which emphasized the variables of geographic regions and distance from cover, respectively.

Initial analysis included regions as a main effect with reduced distance from cover categories. Subsequent designs were based on combined plot data (no geographic differentiation) which permitted extension of distance from cover categories. Chi-square analysis was also conducted to contrast cutblock utilization patterns by harassment category for ungulate species considered individually.

Analysis of Pellet Group Data With Regional Differentiation

Four main effects were tested in this design: harassment, ungulate species, distance from cover and regions. Geographic regions were included to test for interactions involving other independent variables. While local or regional population density differences can be expected, the influence of other independent variables on cutblock utilization is theoretically independent of region.

Distance from cover was limited to 8 categories, ranging from 1 chain inside cover to 6 chains from cover. Distances equal to or greater than 7 chains were clumped in the 6-chain category to provide adequate plot representation at this distance. Similarly, 2 harassment categories versus

4 provided better plot representation for the main effects. Moderately high and high harassment cutblocks were assigned to the high harassment category, with similar clumping of moderately low and low harassment cutblocks.

The data base for analysis was pellet group plot stocking percent, equivalent to the number of pellet groups per species divided by the number of plots per observation cell (Table 6). This index provided a comparative basis for analysis, and could be directly related to days use, assuming a defecation rate per day, period of defecation and sampling intensity. Since a large number of cells had values of 30 percent or less, the data base was transformed via arcsin square root prior to analysis.

Inspection of the data (Table 6) reveals a disjoint distribution of elk, with virtually all recorded activity occurring in the Rocky-Clearwater Forest. Geographical population density variation has been the result of previous distribution patterns, as well as restocking programs (Stelfox 1964) and is generally independent of logging patterns. Because of this variation, elk data were omitted from analyses with regional representation.

Results of analysis of variance indicated significance for simple interactions (harassment x species and species x distance from cover) and the main effects of regions, distance from cover and species (Table 7).

Differences in cutblock utilization were apparent for moose and deer (Figure 4). Moose utilization over distance

Species	Distance From Cover	Grande Prairie Low	Grande Prairie High	Rocky-Clearwater Low	Rocky-Clearwater High	Whitecourt Low	Whitecourt High
Moose	-1	1.9	4.9	5.2	16.7	19.2	8.9
	0	5.9	2.9	3.3	3.5	25.8	16.4
	1	10.9	3.1	4.9	6.7	22.7	12.3
	2	8.2	3.7	4.3	4.5	9.4	10.7
	3	9.5	1.2	2.6	4.9	12.8	8.8
	4	3.7	3.1	5.0	0.0	11.5	7.3
	5	7.7	2.1	5.3	0.0	8.8	1.9
	6+	5.0	2.6	8.3	0.0	19.7	2.8
Deer	-1	1.9	4.9	8.6	11.7	6.8	37.3
	0	5.9	2.9	1.7	5.3	6.4	27.9
	1	3.6	1.6	3.7	9.3	8.2	13.2
	2	6.6	1.2	4.3	9.0	2.8	14.3
	3	3.2	2.4	3.9	6.6	5.8	4.9
	4	3.7	3.1	5.0	1.8	1.9	10.9
	5	0.0	4.2	5.3	3.7	0.0	9.4
	6+	0.0	0.0	0.0	0.0	0.0	0.9
Elk	-1	0.0	0.0	15.5	13.3	0.0	0.0
	0	0.0	0.0	15.0	40.4	0.0	0.0
	1	0.0	0.0	16.0	18.7	1.0	0.0
	2	0.0	0.0	12.9	28.4	0.0	0.0
	3	0.0	0.0	13.2	29.5	2.3	0.0
	4	0.0	0.0	12.5	37.5	0.0	0.0
	5	0.0	0.0	10.5	11.1	0.0	0.0
	6+	0.0	0.0	8.3	30.8	0.0	0.0

Forest and Harassment Category (column group header above Grande Prairie, Rocky-Clearwater, Whitecourt)

Table 6: Pellet group stocking percents with regional differentiation

Source of Variation	Df	SS	MS	F
Regions	2	1009.82	504.91	24.34b
Harassment	1	2.14	2.14	<1
Distance From Cover	7	1111.00	158.71	7.65b
Species	1	145.09	145.09	7.00a
Regions x Har.	2	88.43	44.22	2.13
Regions x Dist.	14	428.09	30.58	1.47
Regions x Species	2	125.15	63.08	3.04
Har. x Dist.	7	235.42	33.63	1.62
Har. x Species	1	527.34	527.34	25.43b
Dist. x Species	7	330.01	47.14	2.27a
Error	51	1058.00	20.74	
Total	95	5061.51		

Table 7: Analysis of variance of pellet group data with regional differentiation. F values followed by an 'a' are significant at P <.05 and values followed by a 'b' are highly significant (P <.01)

from cover was generally more uniform versus deer. For the latter species, high peripheral use as indicated by pellet group counts declined to essentially no use beyond the 6-chain category.

Response to harassment was also different by species (Figure 5). Moose utilization of cutblocks was, as expected, markedly higher in low harassment areas. Deer, however, reversed this pattern for the designated harassment categories with a higher level of use recorded for high harassment cutblocks.

Significant regional variations in ungulate densities were apparent for moose and deer. However, none of the

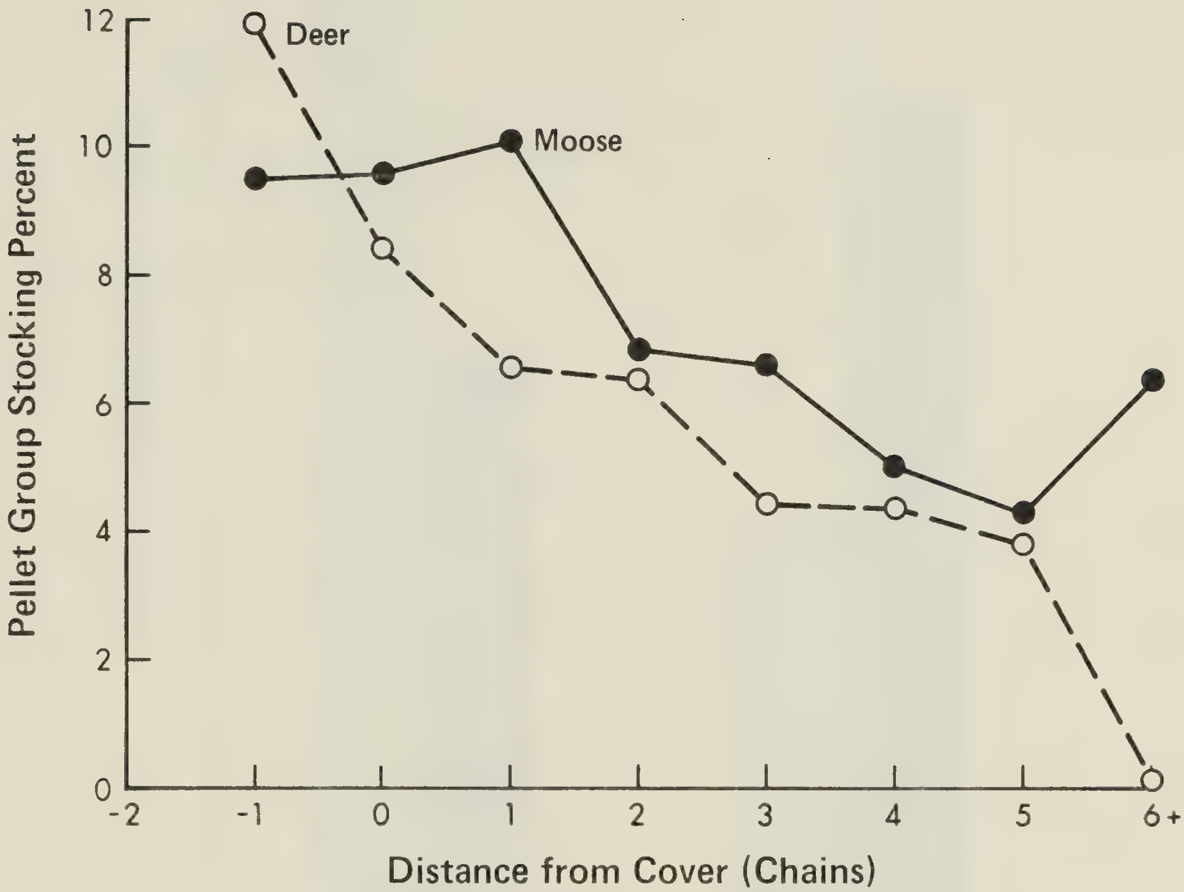


Figure 4: Moose and deer activity over distance from cover. Differences in use curves by species are significant ($p < 0.05$)

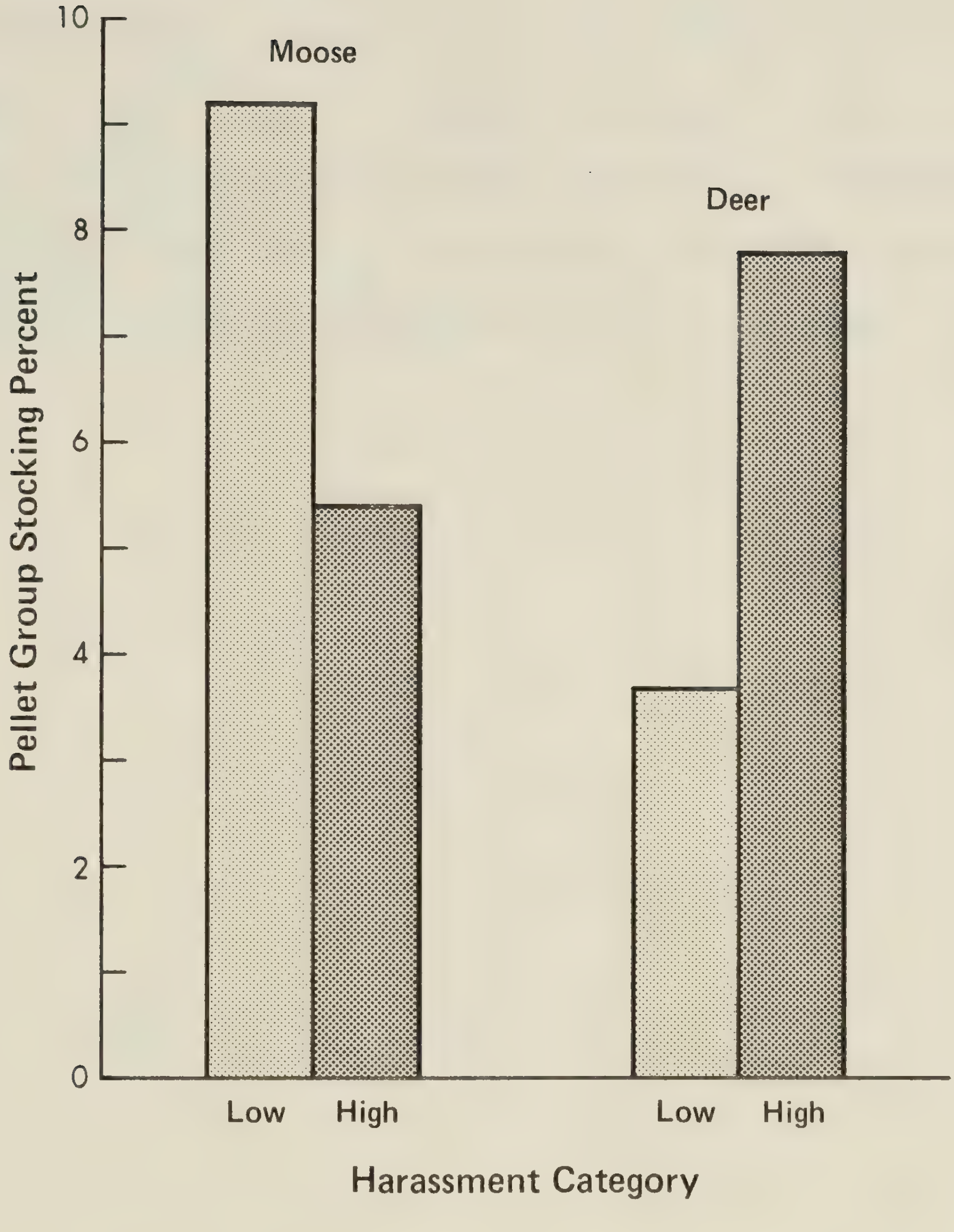


Figure 5: Moose and deer density response to harassment. Differences in species response to harassment are highly significant ($p < 0.01$)

simple interactions involving regions were significant, implying a uniform effect of the independent variables throughout the study area.

Distance from cover as a main effect was highly significant, even with reduced distance from cover categories. The utilization curve (Figure 6), representing moose and deer, indicates a near-linear decline over the whole range of distance categories (up to 6 chains).

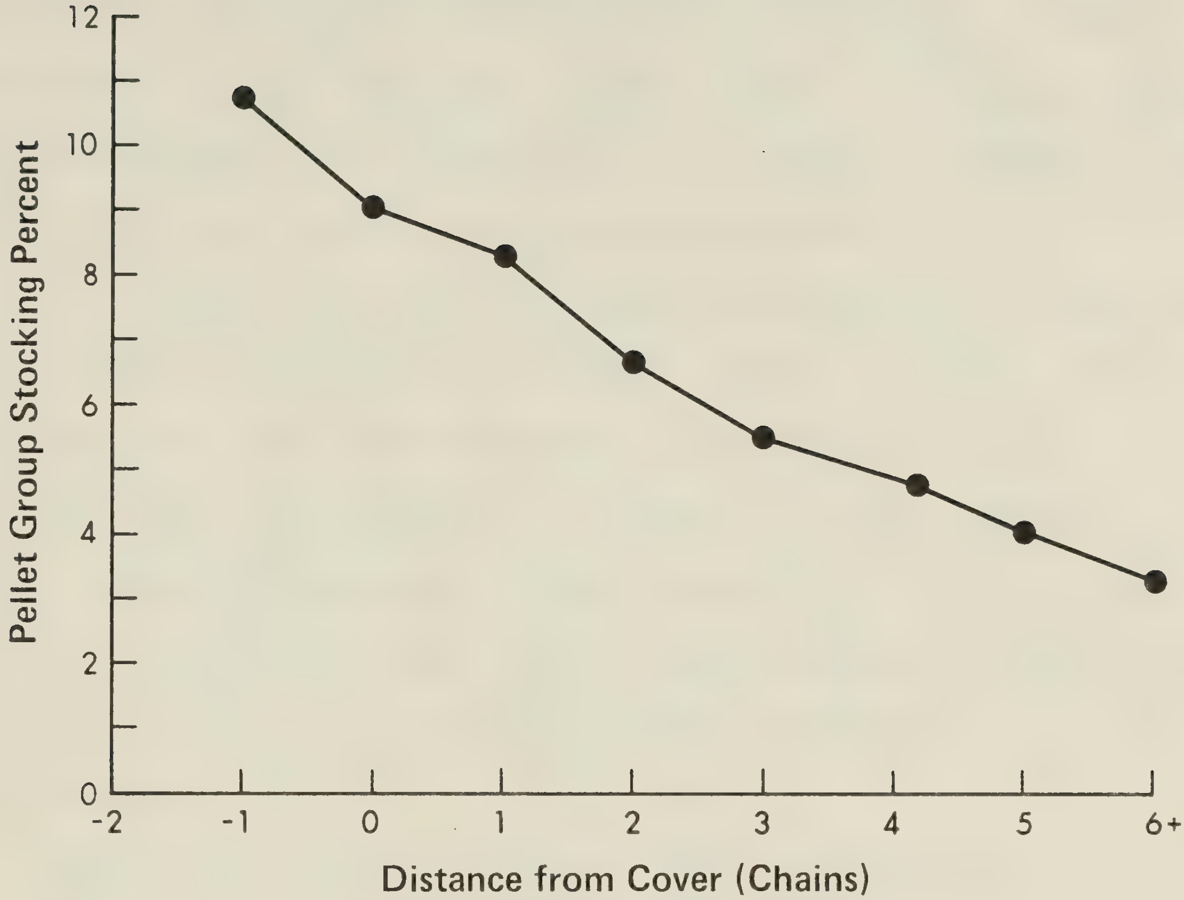


Figure 6: Generalized response curve over distance from cover representing moose and deer. The main effect of distance from cover is highly significant ($p < 0.01$)

Analysis of Shrub Utilization Data With Regional Differentiation

Analysis was conducted by factorial design without replication for three independent variables: regions, harassment and distance from cover. Because shrub utilization was not definable by ungulate species, the latter as a main effect could not be tested.

It should be noted that shrub utilization analysis is not directly comparable to pellet group analysis. Browse utilization by elk was implicitly included in the data base. In addition, utilization of shrubs is also a function of range characteristics, for example, distribution, availability and palatability of browse species. Results do, however, serve tc corroborate trends established by pellet group counts.

Utilization factors (Aldous 1944) were used as the data base for analysis of variance. For each distance category, calculation of shrub utilization factors was as follows:

a. calculation of the average density of each browse species(i)

$$= \frac{\text{sum density of species(i)}}{\text{no. plots in distance category}}$$

b. calculation of the average degree of browsing[1] of each browse species(i)

$$= \frac{\text{sum browsing percents of species(i)}}{\text{no. plots species(i) occurred on}}$$

c. utilization factor for species(i)

=average density(i) x average degree browsing(i)

d. utilization factor for a distance category

=sum utilization factors species((i),i=1,n)

The procedure accounts for both browsing preference and relative abundance of shrubs. A modification of the procedure reported by Aldous (1944) is calculation of utilization factors for distance from cover categories within harassment and regional categories (Table 8).

Analysis results revealed a significant interaction for regions x harassment (Table 9); an apparent contradiction of previous pellet group analysis. Inspection of the data (Table 8) suggests that shrub utilization in the high harassment category of the Whitecourt Forest caused the apparent anomaly. Heaviest browsing occurred at or near the cutblock periphery where the potential impact of harassment is mitigated. Intensity of use may be attributable to the relatively high density of deer in the area (Table 6).

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[1] Average browsing percent for each species was taken at the midpoint of recorded browsing percent categories.

Forest	Distance From Cover	Harassment Category	
		Low	High
Grande Prairie	-1	37.2	43.7
	0	112.5	2.9
	1	55.1	4.4
	2	125.0	4.1
	3	75.1	2.3
	4	37.3	2.7
	5	71.1	5.0
	6+	19.5	1.4
Rocky-Clearwater	-1	190.8	76.6
	0	116.6	116.5
	1	100.5	35.0
	2	92.8	48.6
	3	116.2	29.0
	4	48.0	44.3
	5	83.6	5.2
	6+	112.5	16.1
Whitecourt	-1	84.8	321.8
	0	42.3	208.1
	1	55.5	139.3
	2	38.1	55.2
	3	77.5	93.8
	4	33.6	53.2
	5	32.1	93.2
	6+	43.6	5.6

Table 8: Shrub utilization factors with regional differentiation

Source of Variation	Df	SS	MS	F
Regions	2	21404.23	10702.12	5.17a
Harassment	1	3222.93	3222.93	1.56
Distance From Cover	7	42068.48	6009.78	2.90a
Regions x Har.	2	45153.52	22576.76	10.91b
Regions x Dist.	14	22867.52	1633.39	<1
Har. x Dist.	7	12456.33	1779.48	<1
Error	14	28975.54	2069.68	
Total	47	176148.55		

Table 9: Analysis of variance of shrub utilization data with regional differentiation. F values followed by an 'a' are significant at P <.05, and values folowed by a 'b' are highly significant (P <.01)

Previous analysis also indicated that deer were not adversely affected by harassment.

Distance from cover as a main effect was significant, with the utilization curve (Figure 7) corroborating trends established by pellet group analysis. Shrub utilization peaked within cutblock edges and generally declined with increasing distance from cover.

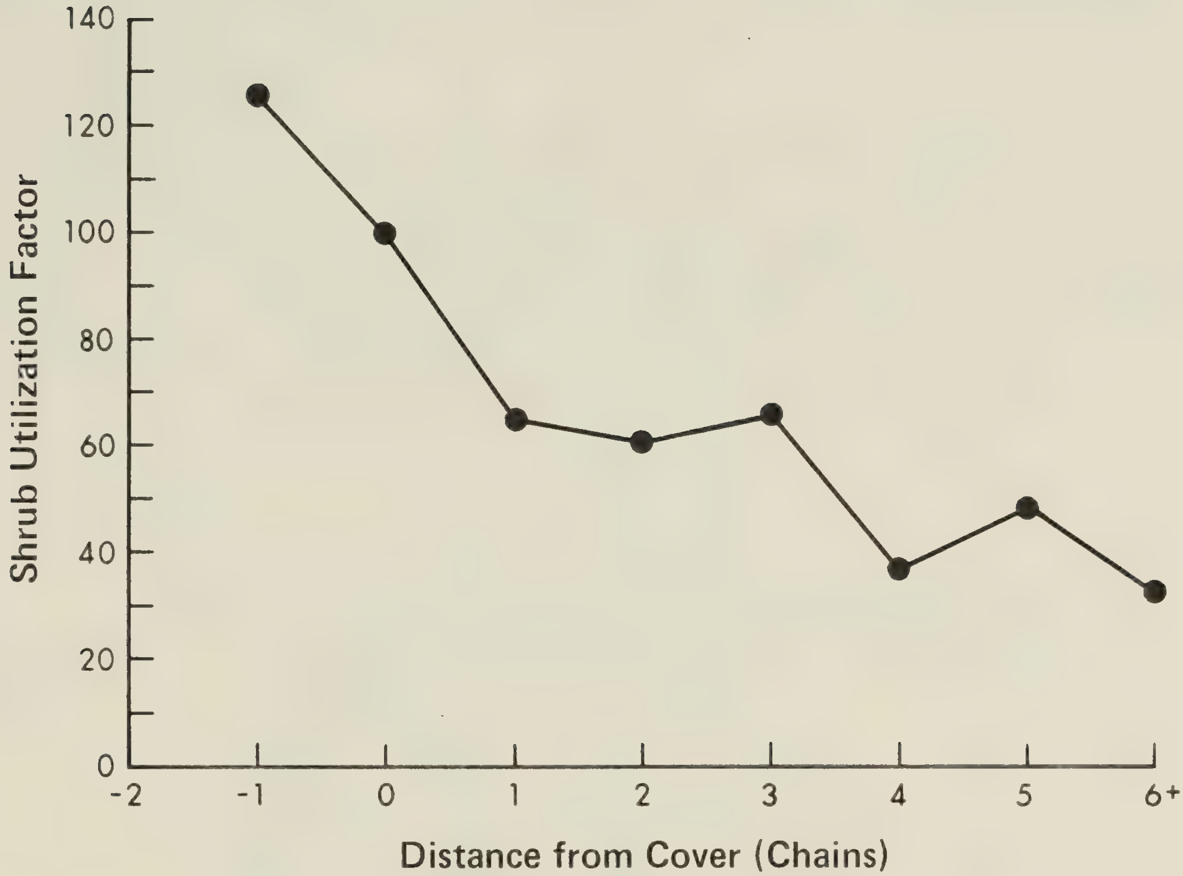

Figure 7: Shrub utilization over distance from cover. The main effect of distance from cover is highly significant ($p < 0.05$)

Analysis of Combined Pellet Group Data

Factorial analysis of variance focused attention on the independent variable of distance from cover by extension of distance categories. Clumping of plot data yielded 9 categories, representing a maximum defined distance of 8 chains from cover.

The data base was, as previously, pellet group stocking percent, recalculated by distance from cover and harassment category for ungulate species (Table 10). Since the effect of regions was eliminated, elk data were included for

Distance From Cover	Harassment Category and Species					
	Moose		Deer		Elk	
	Low	High	Low	High	Low	High
-1	9.8	10.7	6.0	20.2	4.9	4.8
0	13.7	8.6	4.3	13.8	6.5	13.2
1	13.7	8.2	5.6	9.0	6.0	6.9
2	7.3	6.5	4.2	8.2	4.6	8.2
3	8.4	5.3	4.4	4.5	5.3	7.3
4	7.6	3.5	3.4	5.6	4.2	8.4
5	7.6	1.6	1.3	6.2	2.5	4.7
6-7	12.2	1.8	0.0	0.6	0.9	4.8
8+	14.3	3.1	0.0	0.0	0.0	1.0

Table 10: Pellet group stocking percents for combined plot data

analysis. Percent values were again transformed by arcsin square root prior to analysis.

Results of data analysis were parallel to previous pellet group analysis in that the interactions involving species were significant (Table 11). Differences in cutblock

Source of Variation	Df	SS	MS	F
Harassment	1	16.47	16.47	2.10
Distance From Cover	8	771.10	96.39	12.29b
Species	2	186.95	93.47	11.92b
Har. x Dist.	8	56.21	7.03	1.12
Har. x Species	2	324.20	162.10	20.67b
Dist. x Species	16	363.56	22.72	2.90a
Error	16	125.50	7.84	
Total	53	1843.99		

Table 11: Analysis of variance of combined pellet group data. F values followed by an 'a' are significant at P <.05 and values followed by a 'b' are highly significant (P <.01)

utilization trends were pronounced for moose versus deer and elk at greater distances from cover (Figure 8). Although deer and elk use was comparable beyond cutblock edges, activity of the former species peaked inside cover while elk use was maximum at the edge.

Again, no significant deviation was found in the pattern of cutblock utilization trends by harassment

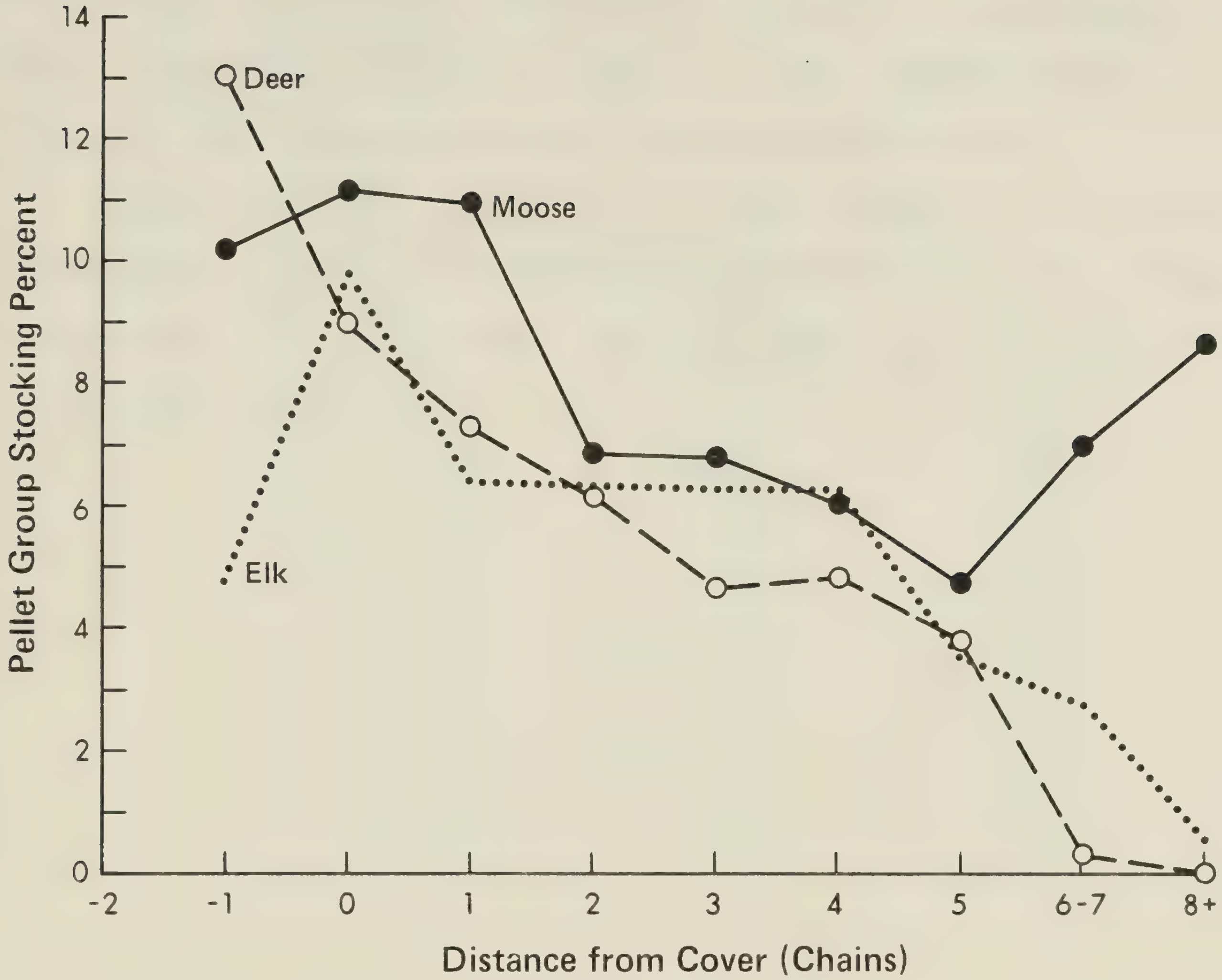

Figure 8: Moose, deer and elk activity over distance from cover. The graph represents combined plot data and differences in use curves by species are highly significant ($p < 0.01$)

category. Individual species variation by distance from cover (Figure 4 and 8) tended to depress the interaction effect (harassment x distance from cover).

Moose and deer response to harassment (Figure 9) confirmed previously established trends for these species. Elk response was similar to deer in that a higher degree of activity was recorded on high harassment cutblocks.

Distance from cover as a main effect was highly significant. Except for within-cover utilization, the curve illustrates a near-linear decline with increased distance from cover (Figure 10).

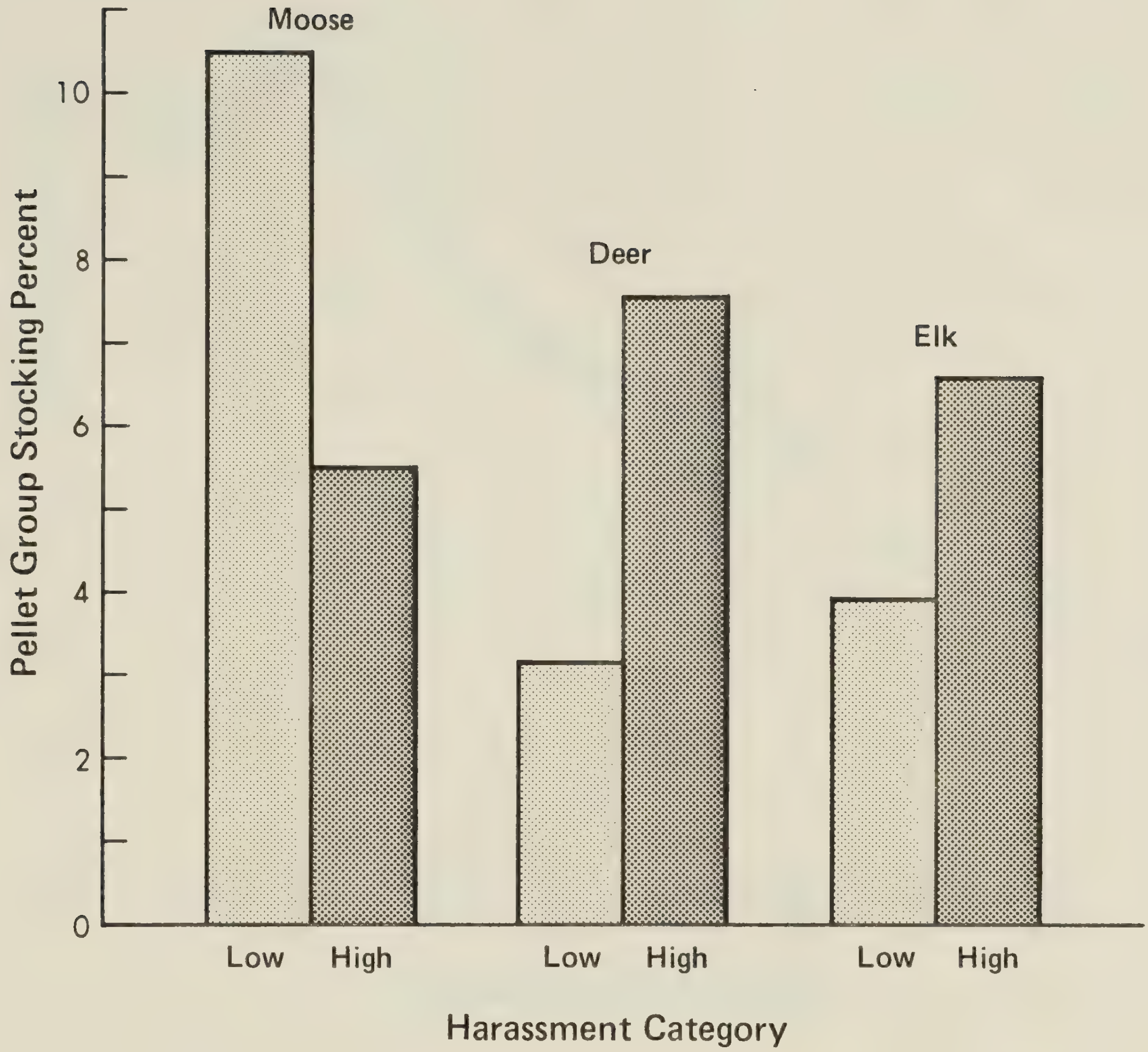

Figure 9: Species density response to harassment. The graph represents combined plot data and differences in species response to harassment are highly significant ($p < 0.01$)

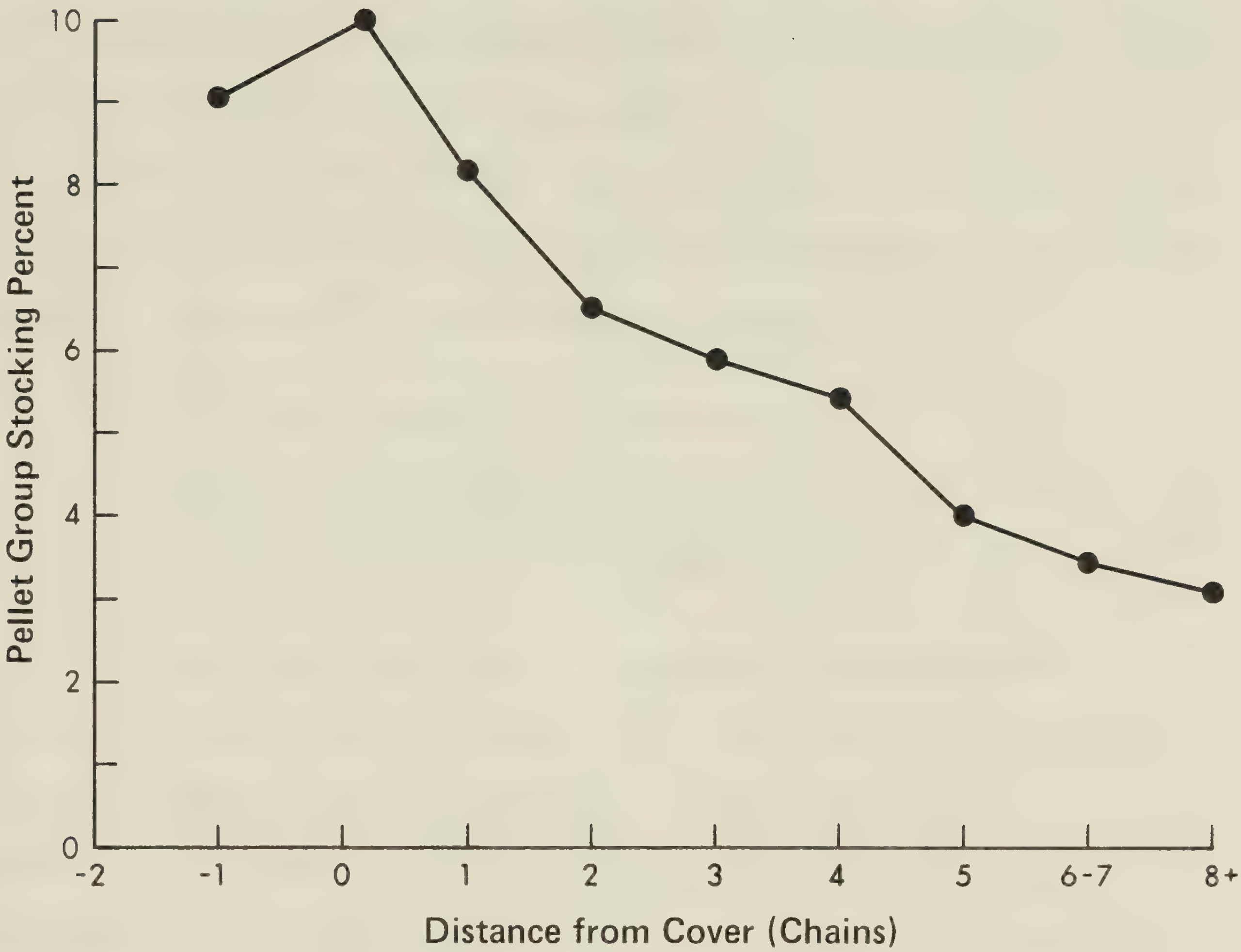

Figure 10: Generalized response curve over distance from cover representing moose, deer and elk. The main effect of distance from cover is highly significant ($p < 0.01$)

Analysis of Relative Use Combined Pellet Group Data

The concept of relative use was introduced into the analysis to assess intraspecific differences in use patterns due to harassment. Local differences in population densities and individual variation by species in cutblock use masked effects attributable to harassment.

Relative use values for distance categories were calculated for each combination of harassment category and ungulate species by the following method:

Relative use percent for distance(i)

$$= \frac{\text{pellet group stocking percent for distance(i)}}{\text{sum stocking percent (distance(i), i=1, n)}} \times 100$$

Utilization data was therefore standardized on a percent basis, with total use for each combination of ungulate species and harassment category equated to 100 percent. Relative use harassment contrasts were then analyzed by the chi-square statistic based on procedures reported by Neu *et al.* (1974).

The null hypothesis states no difference in expected use occurs from observed use over distance from cover. For 9 distance categories, expected or uniform becomes 100 percent divided by 9 distance categories, or 11.1 percent per distance category (Table 12).

Relative use trends for moose in low harassment cutblocks did not deviate significantly from uniform, or

Species	Distance From Cover	Expected Relative Use(T)	Observed Relative Use by Harassment Category			
			Low	$(O-T)^2/T$	High	$(O-T)^2/T$
Moose	-1	11.1	10.4	.044	21.7	10.122
	0	11.1	14.5	1.041	17.4	3.576
	1	11.1	14.5	1.041	16.6	2.725
	2	11.1	7.7	1.041	13.2	3.973
	3	11.1	8.9	.436	10.8	.008
	4	11.1	8.0	.866	7.1	1.441
	5	11.1	8.0	.866	3.2	5.622
	6-7	11.1	12.9	.292	3.6	5.068
	8+	11.1	15.1	1.441	6.3	2.076
			Chi²=	7.07	Chi²=	34.61a
Deer	-1	11.1	20.5	7.960	29.7	31.168
	0	11.1	14.7	1.676	20.3	7.625
	1	11.1	19.2	5.911	13.2	.397
	2	11.1	14.4	.981	12.0	.073
	3	11.1	15.1	1.441	6.6	1.824
	4	11.1	11.6	.022	8.2	.758
	5	11.1	4.4	4.044	9.1	.360
	6-7	11.1	0.0	11.100	0.9	9.373
	8+	11.1	0.0	11.100	0.0	11.100
			Chi²=	44.26a	Chi²=	62.67a
Elk	-1	11.1	14.0	.758	8.1	.811
	0	11.1	18.6	5.068	22.3	11.301
	1	11.1	17.2	3.352	11.6	.022
	2	11.1	13.2	.397	13.8	.657
	3	11.1	15.2	1.514	12.3	.130
	4	11.1	12.0	.073	14.2	.866
	5	11.3	7.2	1.370	7.9	.922
	6-7	11.1	2.6	6.509	8.1	.811
	8+	11.1	0.0	11.100	1.7	7.960
			Chi²=	30.14a	Chi²=	23.48a

Table 12: Chi-square analysis of relative use pellet group data by harassment category for clearcuts. Chi² values followed by an 'a' deviate significantly ($P < .01$) from expected use

expected use (Figure 11). In contrast, use curves in high harassment cutblocks deviated significantly from uniform use over distance from cover. Relative use declined in a near-linear fashion and was below expected beyond 3 chains from cover.

Relative use for deer was significantly different from the uniform use curve for both harassment categories (Figure 12). Low harassment utilization was somewhat more stable, and above average to 4 chains from cover. Although both relative use curves were similar in shape, the major point of difference was inside cover where a higher percent of high harassment utilization occurred.

Relative use patterns for elk were parallel to deer in that both curves were significantly different from uniform use (Figure 13). While elk utilization for both harassment categories was below expected beyond 4 chains from cover, the low harassment use curve tended to be somewhat more stable versus its high harassment counterpart.

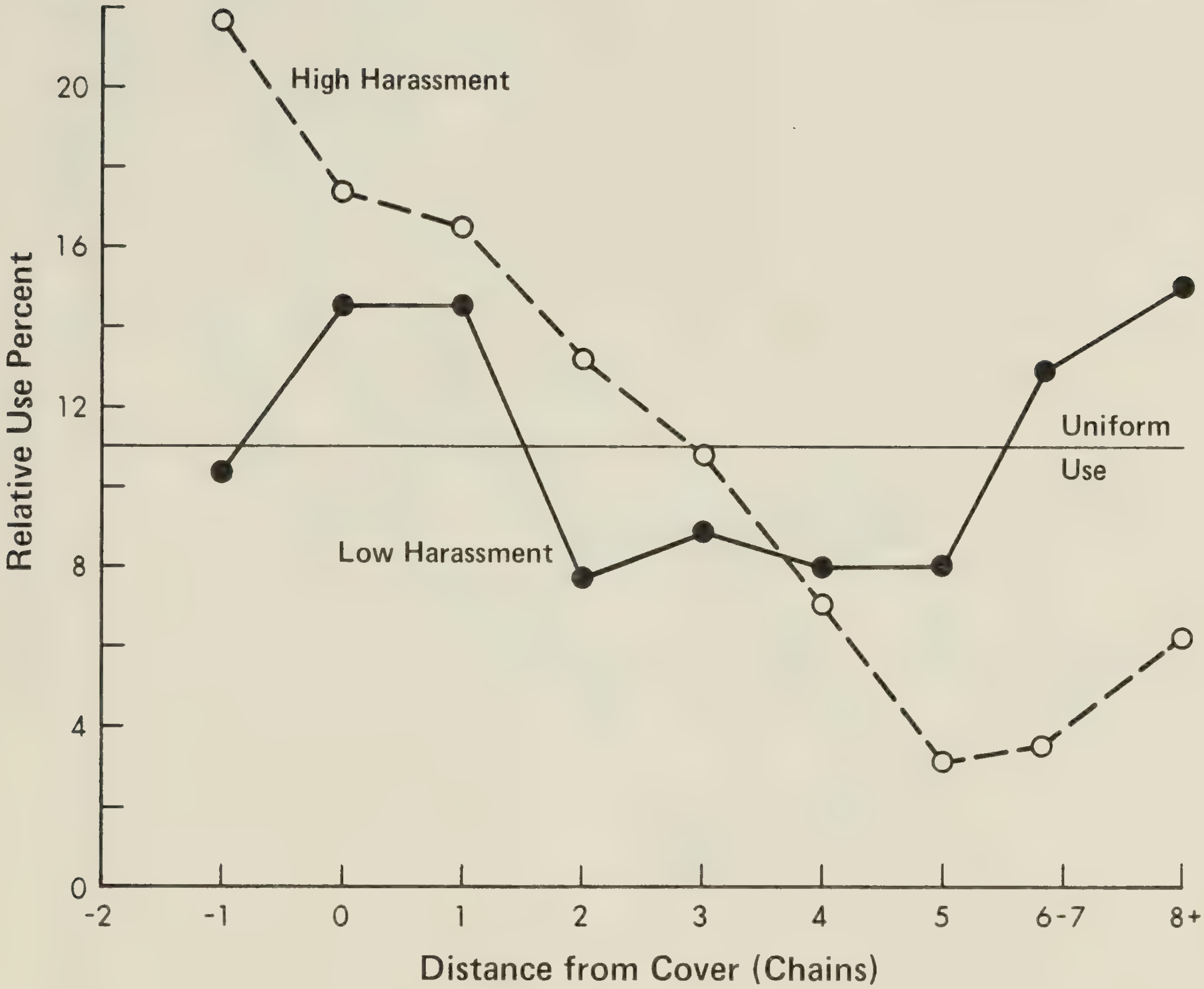

Figure 11: Moose relative use contrasts by harassment category. Low harassment use does not deviate significantly from uniform or expected use. High harassment use is significantly different ($p < 0.01$)

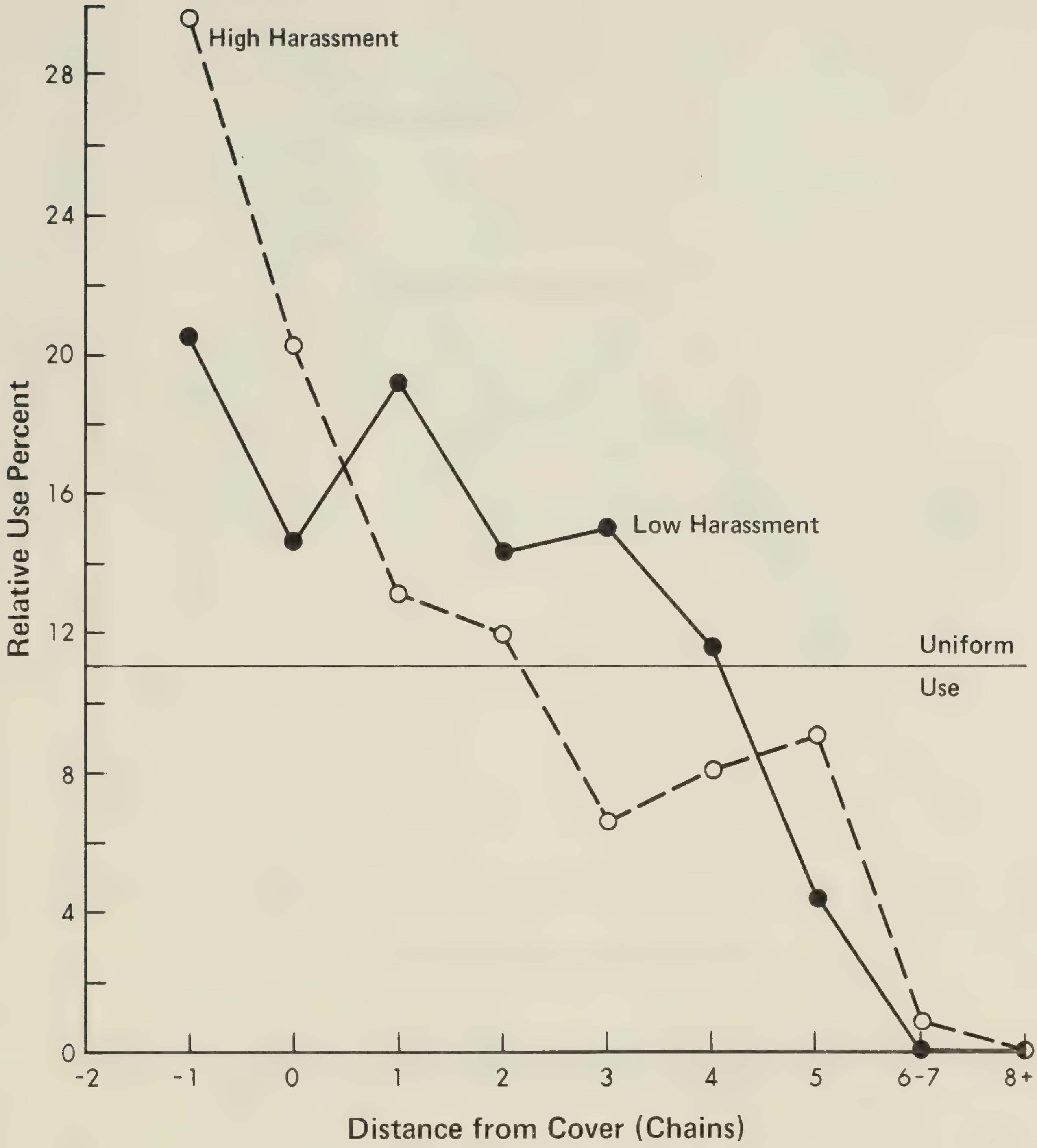

Figure 12: Deer relative use contrasts by harassment category. Both curves deviate significantly from uniform or expected use ($p < 0.01$)

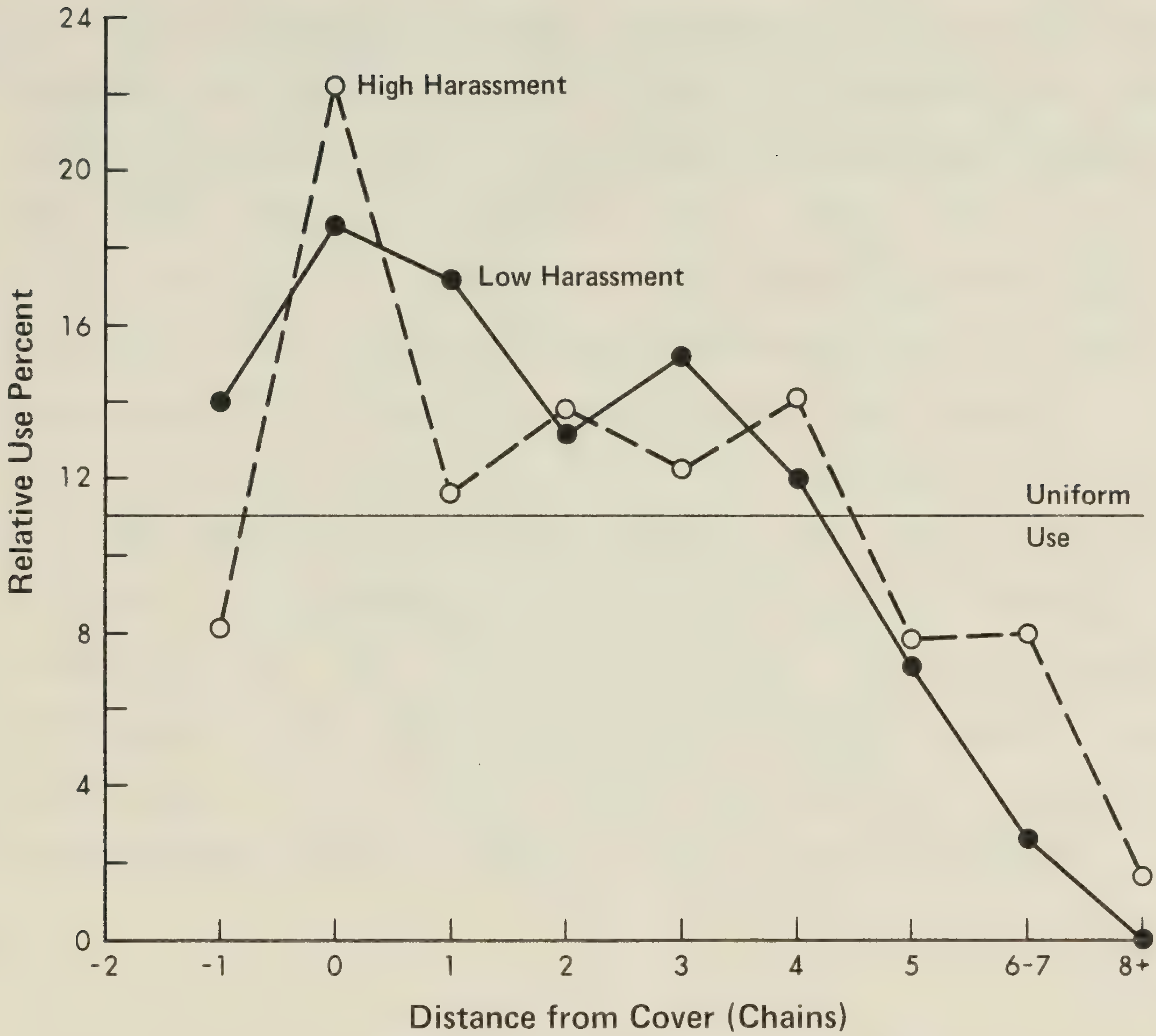

Figure 13: Elk relative use contrasts by harassment category. Both curves deviate significantly from uniform or expected use ($p < 0.01$)

Analysis of Relative Use Shrub Utilization Data

The data base for calculation of relative use values was shrub utilization factors, delineated by harassment and distance from cover categories (Table 13). Expected use was again 11.1 percent, based on 9 distance categories. For each harassment category, relative use values were then calculated by the percent of total shrub utilization that occurred in each distance category. Note that derived values represented elk, as well as deer and moose utilization.

The relative use curve for low harassment was not significantly different from expected use (Figure 14). In contrast, high harassment use was significantly different, resulting in the rejection of the null hypothesis. Differences in the two curves are particularly evident for within-cover utilization, where high harassment use was approximately twice that of the low harassment category.

Harassment Category	Distance From Cover	Shrub Use Factors	Relative Use		
			Observed	Expected (T)	$(O-T)^2/T$
Low	-1	107.3	15.6	11.1	1.814
	0	97.6	14.2	11.1	.859
	1	83.3	12.1	11.1	.088
	2	80.4	11.7	11.1	.031
	3	87.1	12.7	11.1	.227
	4	42.8	6.2	11.1	2.171
	5	59.0	8.6	11.1	.568
	6-7	29.6	4.3	11.1	4.175
	8+	100.6	14.6	11.1	1.096
					Chi^2= 11.03
High	-1	154.4	30.5	11.1	33.906
	0	124.2	24.5	11.1	16.177
	1	65.2	12.9	11.1	.292
	2	34.9	6.9	11.1	1.589
	3	34.7	6.9	11.1	1.589
	4	37.5	7.4	11.1	1.233
	5	45.4	9.0	11.1	.397
	6-7	4.2	0.8	11.1	9.558
	8+	5.7	1.1	11.1	9.009
					Chi^2= 73.75a

Table 13: Chi-square analysis of relative use shrub utilization data by harassment category for clearcuts. Chi^2 values followed by an 'a' are highly significant ($P < .01$)

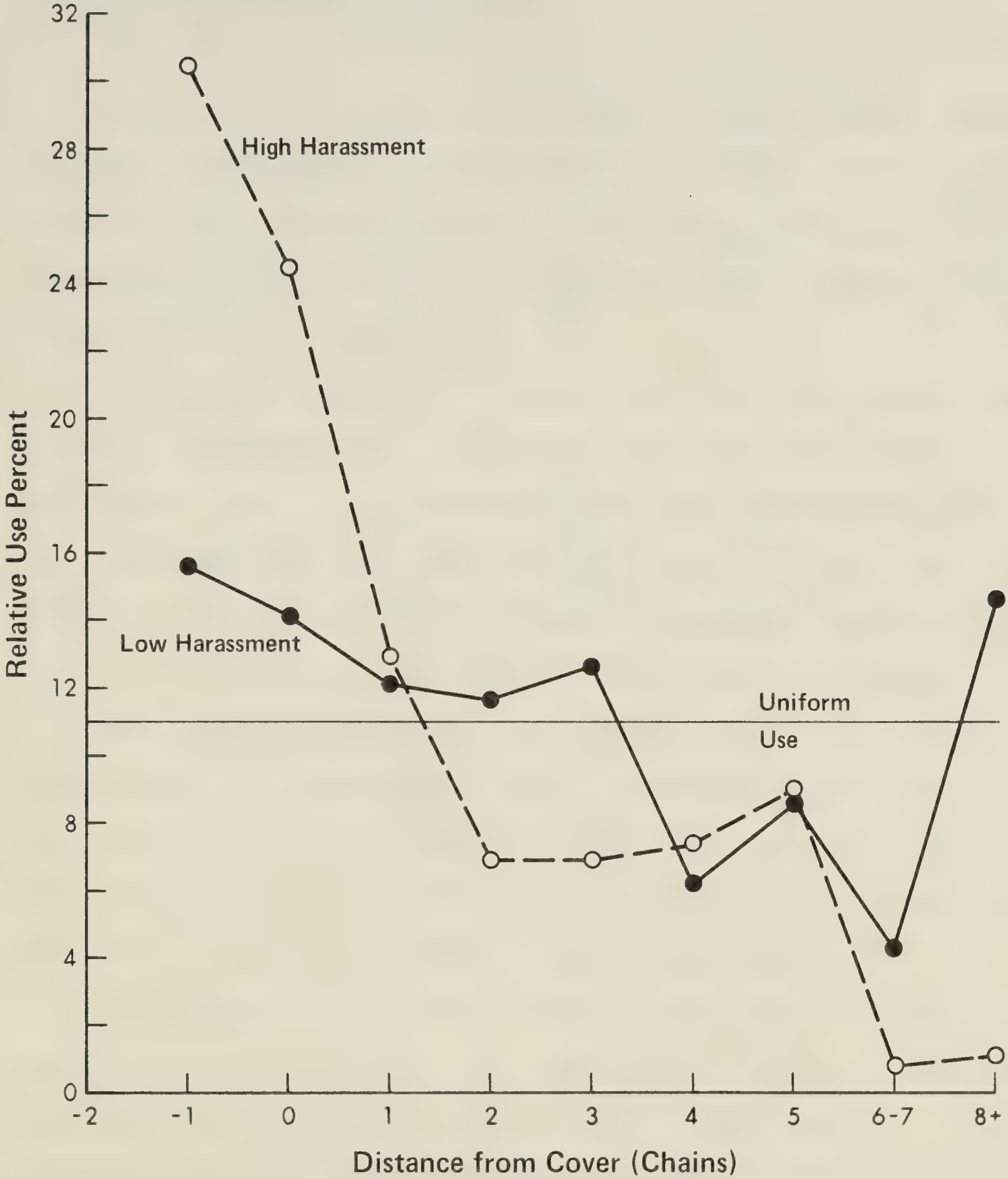

Figure 14: Shrub relative use contrasts by harassment category. High harassment utilization deviates significantly ($p < 0.01$) from uniform or expected use. Low harassment use is not significantly different from expected

Utilization Patterns on Partial Cuts

Analysis of Relative Use Pellet Group Data for Partial Cuts

Relative use values were derived from pellet group stocking percents, calculated by distance from cover category for combined partial cut data. Seven distance categories were designated, representing a maximum of 17 chains from cover (Table 14).

Chi-square analysis of partial cut data was similar to previous relative use analysis. However, contrasts in harassment were not definable. The null hypothesis states that observed use does not deviate from uniform use on partial cuts. Based on 7 distance categories, expected use becomes 14.1 percent of total use per distance category.

Use curves for deer and moose did not deviate significantly from expected use in accordance with the null hypothesis (Figure 15). Deer activity did, however, peak at the periphery of cut areas. Moose utilization maximized at 2-3 chains and was relatively even beyond this point.

In contrast to the above trends, elk relative use was restricted exclusively to peripheral areas and was significantly different from expected or uniform use. Approximately 75 percent of observed elk activity occurred in the first distance category, and declined sharply thereafter. No elk pellet groups were found beyond the third distance category (4-6 chains).

Species	Distance From Cover	Stocking Percent	Relative Use Observed	Relative Use Expected (T)	(O-T)²/T
Moose	up to 1	5.6	11.9	14.3	.403
	2-3	9.6	20.3	14.3	2.517
	4-6	6.7	14.3	14.3	0.000
	7-9	5.5	11.7	14.3	.473
	10-12	7.0	14.9	14.3	.025
	13-16	6.7	14.2	14.3	.001
	17+	6.0	12.8	14.3	0.157
				Chi²=	3.58
Deer	up to 1	3.1	23.6	14.3	5.996
	2-3	1.7	13.1	14.3	.099
	4-6	2.0	15.2	14.3	.054
	7-9	2.1	15.6	14.3	.188
	10-12	2.0	15.1	14.3	.042
	13-16	1.1	8.4	14.3	2.451
	17+	1.2	9.1	14.3	1.898
				Chi²=	10.66
Elk	up to 1	12.5	72.2	14.3	234.400
	2-3	3.5	20.2	14.3	2.430
	4-6	1.3	7.5	14.3	3.230
	7-9	0.0	0.0	14.3	14.300
	10-12	0.0	0.0	14.3	14.300
	13-16	0.0	0.0	14.3	14.300
	17+	0.0	0.0	14.3	14.300
				Chi²=	297.26a

Table 14: Chi-square analysis of relative use pellet group data for partial cuts. Chi² values followed by an 'a' are highly significant ($P < .01$)

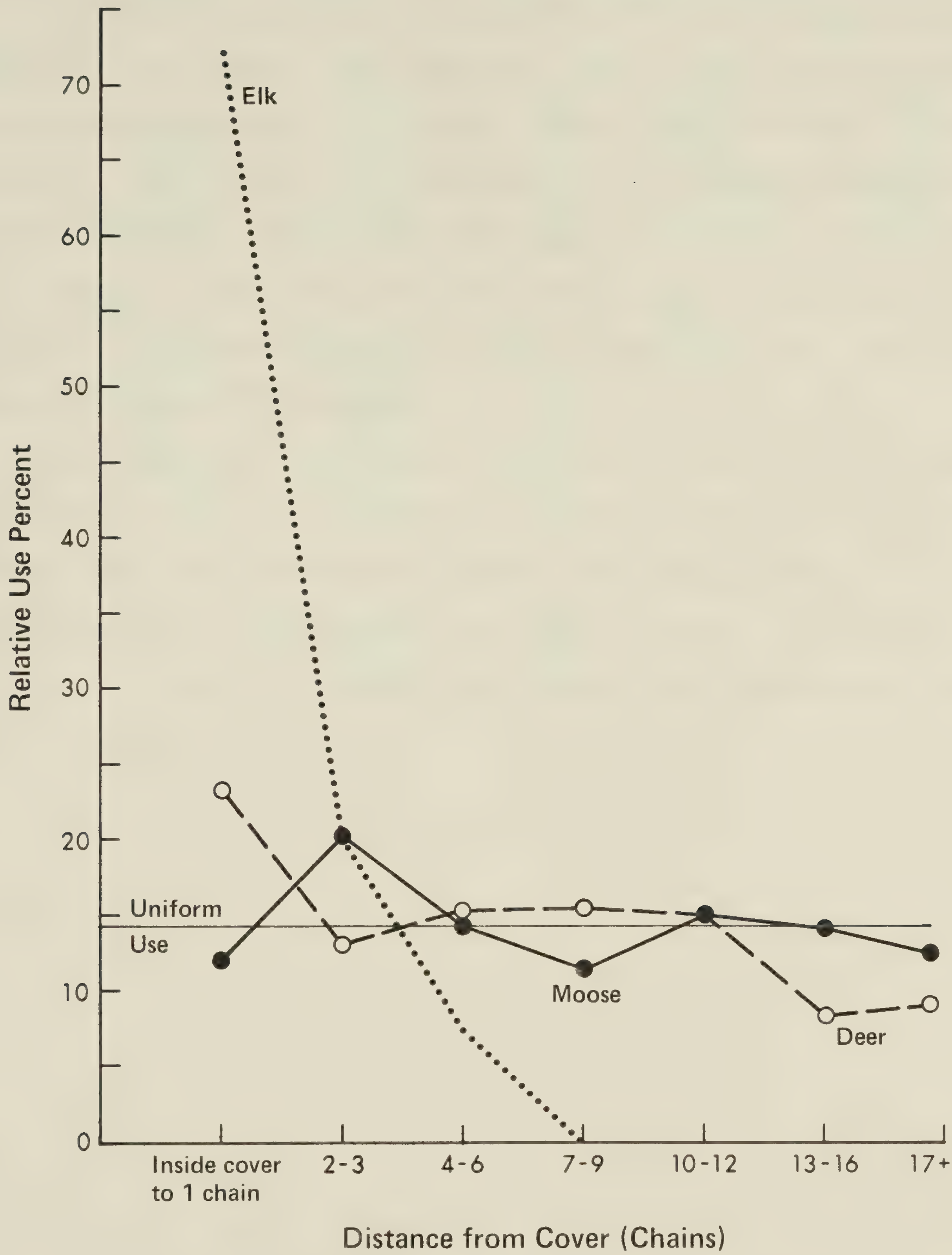

Figure 15: Partial cut relative use contrasts by species. Elk relative use deviates significantly ($p < 0.01$) from uniform or expected use. Moose and deer curves are not significantly different

Analysis of Relative Use Shrub Utilization Data for Partial Cuts

Relative use values were derived from shrub utilization factors, delineated by distance from cover categories. Analysis was parallel to pellet group data analysis for partial cuts with the exception of no differentiation by ungulate species (Table 15). The hypothesis of no deviation in observed use from expected use was tested for combined partial cut shrub utilization data, as well as for partial cuts considered individually.

The relative use curve for combined partial cut data conformed to the null hypothesis, with utilization generally uniform over the designated distance categories (Figure 16). Although general differences are evident among utilization curves by region, no significant deviation from uniform use occurred (Figure 17).

Partial Cut	Distance From Cover	Utilization Factor	Relative Use Observed	Relative Use Expected (T)	$(O-T)^2/T$
G5 S12	up to 1	120.8	17.7	14.3	.808
	2-3	96.9	14.2	14.3	.001
	4-6	89.2	13.1	14.3	.101
	7-9	141.9	20.8	14.3	2.954
	10-12	108.9	16.0	14.3	.202
	13-16	79.0	11.6	14.3	.510
	17+	46.2	6.8	14.3	3.934
				Chi^2=	8.51
G7 L1A	up to 1	93.6	22.1	14.3	4.254
	2-3	56.0	13.2	14.3	.085
	4-6	41.4	9.8	14.3	1.416
	7-9	50.4	11.9	14.3	.403
	10-12	65.8	15.5	14.3	.101
	13-16	69.7	16.5	14.3	.338
	17+	46.1	10.9	14.3	.808
				Chi^2=	7.40
R9 L3	up to 1	17.6	14.9	14.3	.025
	2-3	20.5	17.3	14.3	.629
	4-6	20.5	17.3	14.3	.629
	7-9	18.9	15.9	14.3	.179
	10-12	14.3	12.0	14.3	.370
	13-16	9.9	8.3	14.3	2.517
	17+	16.9	14.2	14.3	.001
				Chi^2=	4.35
Combined Plot Data	up to 1	36.7	13.1	14.3	.101
	2-3	47.2	16.9	14.3	.473
	4-6	42.1	15.1	14.3	.045
	7-9	32.4	11.6	14.3	.510
	10-12	44.3	15.9	14.3	.179
	13-16	32.7	11.7	14.3	.473
	17+	43.9	15.7	14.3	.137
				Chi^2=	1.92

Table 15: Chi-square analysis of relative use shrub utilization data for partial cuts. All Chi^2 values are not significant ($P < .05$)

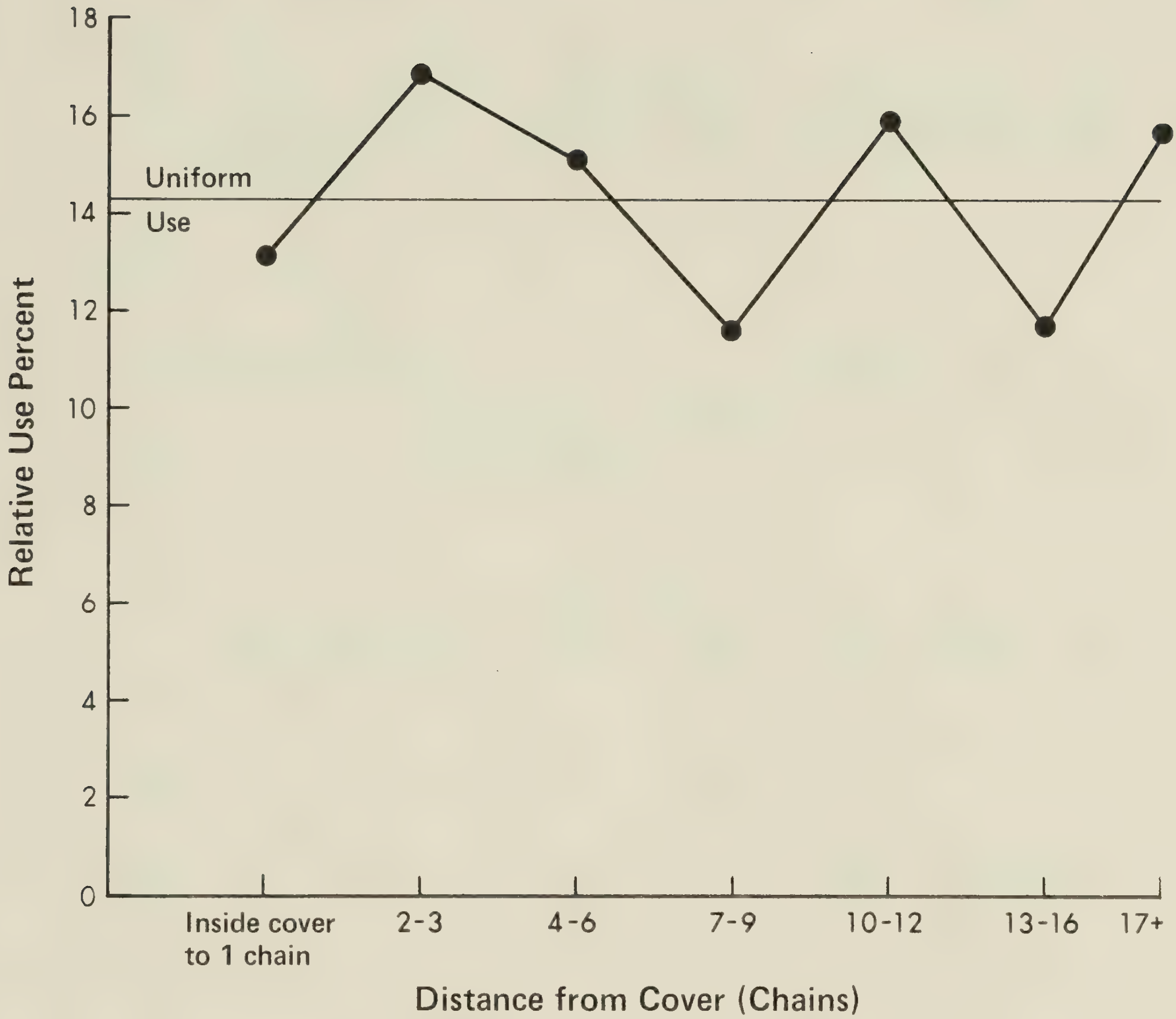

Figure 16: Shrub relative use curve for combined partial cut areas. Shrub utilization does not deviate significantly from uniform or expected use

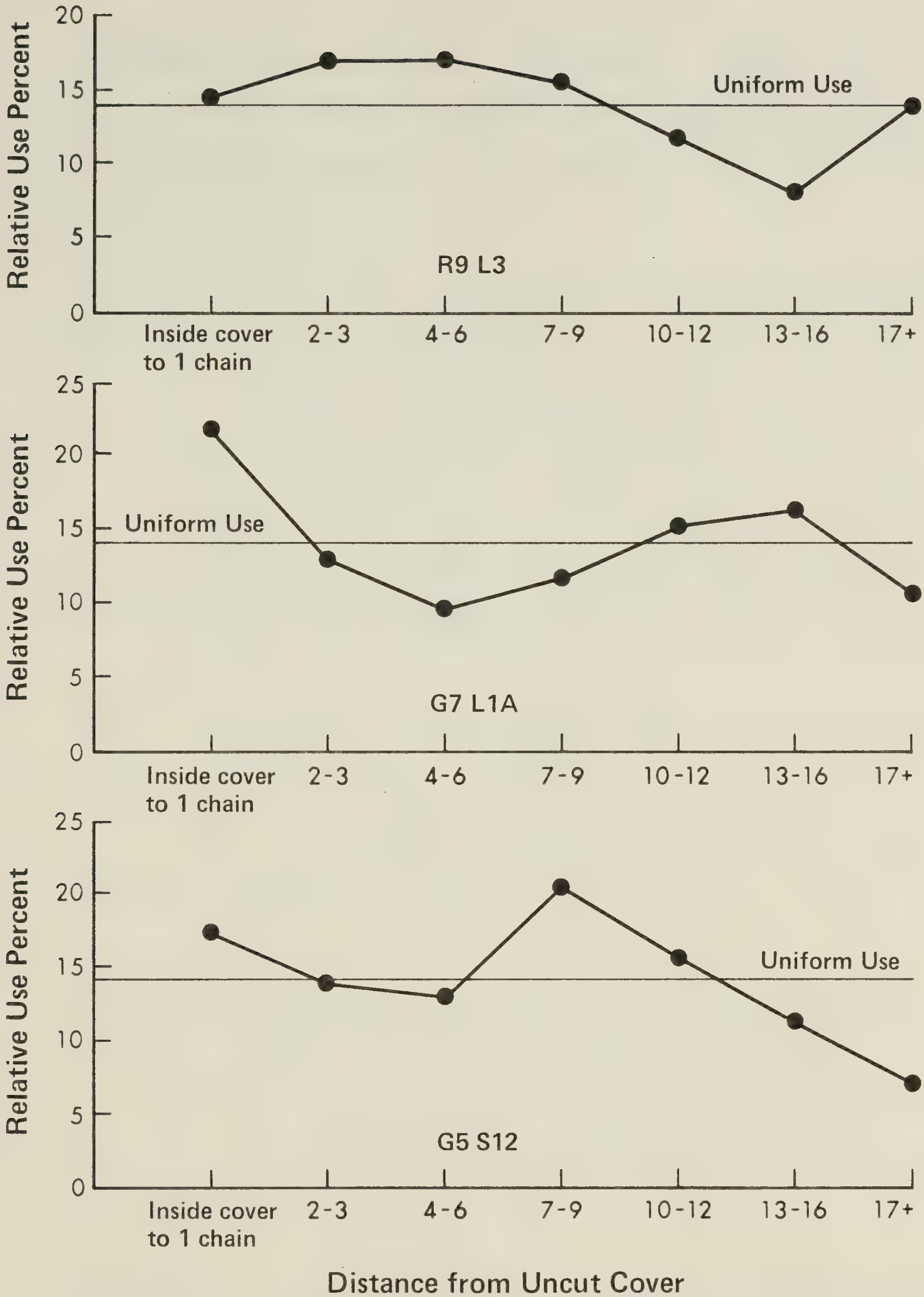

Figure 17: Shrub relative use curves by partial cut area. All curves do not deviate significantly from uniform or expected use

Models of Cutblock Utilization

Multiple Classification Analysis (MCA) was the technique used for model formulation. A complete description of MCA is given by Andrews et al. (1973), and only a cursory review is presented here.

This computer-based technique is essentially multiple regression using dummy variables, and is an extension of analysis of variance. An advantage of MCA over analysis of variance is that, for 2 or more interrelated factors, the pattern of relationship of a predictor to the dependent variable is indicated. However, any significant interactions among predictor variables must be identified and eliminated prior to analysis.

Other advantages of MCA include the ability to handle non-linear relationships, correlated predictors and predictors on a nominal scale. The latter involves categorization without ranking, for example, topographic class description.

Assumptions regarding the scaling of predictors, or the form of relationship of predictor variables to the dependent variable are not required. Categorization of the data base into exhaustive and mutually-exclusive classes is, however, a requirement.

Adjustments for intercorrelations among predictors are made during analysis, and both adjusted and unadjusted results presented in the program output. The adjustments

essentially correct for 'non-orthogonalities' with adjusted means representing multiple regression estimates of what mean values would have been if the analysis was conducted on a similar but different data set. Large differences in these values make inferences beyond the data set questionable.

The major limitation of MCA in model formulation is related to theoretical implications dealing with sample size. Because of the large number of degrees of freedom associated with analysis, categories of predictors require a relatively large number of cases (observations) for reasonably stable estimates of means. Futhermore, the number of cases should be substantially greater than degrees of freedom. A general guideline adhered to in model formulation was that the number of categories across all predictors approximately equaled 10 percent of n observations.

The input data consisted of dependent and independent variable categorizations of 57 individual cutblocks. Based on the limitations imposed by sample size, the number of predictors for each MCA test was limited to 3, with a maximum of 4 categories or subgroups per predictor. A total of 12 predictors were tested by MCA, describing habitat diversity indices, forage characteristics, cover, year of cut, site treatment and harassment (Table 16).

The best set of predictors for the dependent variable was chosen on the basis of multiple correlation coefficients (R^2) or the predictive power of the model. Additional predictor variables were evaluated on an individual basis by

Habitat Diversity Indices: Cutblock size Edge/unit area Topography Interspersion of cutblocks	Forage Variables: Density of forbs Density of grasses Total density of shrubs Average height of shrubs Density of browsing shrubs
Harassment	Cover: Species composition, density and height of cover
Site treatment	
Year of cut	

Table 16: List of predictor variables tested by MCA for moose and deer utilization of cutblocks

substitution into the best model. However, the majority of predictors tested proved insignificant or of limited value in explaining the variance of the dependent variable with only 6 used in model development.

Data subclasses were determined by natural groupings as suggested by the data, interpretation of results and restrictions imposed by sample size. While it was possible to obtain different results by manipulating data categories, the final subgroups generally provided the best 'fit' for the variation of the dependent variable (Table 17).

The dependent variables of moose and deer utilization were described by subclasses of pellet group stocking percent, calculated for each cutblock (Table 17). Elk data were not incorporated into a model because of the skewed geographic distribution of the species in the study area.

Dependent variables:

Stocking Percent (moose and deer)

Class	Class Limits	Class	Class Limits
1.	0%	5.	16 - 20%
2.	up to 5%	6.	21 - 25%
3.	6 - 10%	7.	26 - 30%
4.	11 - 15%	8.	31 - 50%
		9.	51% +

Independent variables:

Cutblock Size

Class	Acres
1.	0 - 40
2.	41 - 80
3.	81+

Edge/unit Area

Class	Chains/acre
1.	.51 - 2.00
2.	2.01 - 2.50
3.	2.51 - 3.00
4.	3.01 +

Block Dispersion Index

Class	Chains
1.	up to 20
2.	21 - 40
3.	41 - 80
4.	81 - 160

Harassment

Class	Description
1.	Low
2.	Mod. Low
3.	Mod. High
4.	High

Site Treatment

Class	Description
1.	No treatment
2.	Scarified, or burned and scarified

Topography

Class	Description
1.	Undulating
2.	Rolling
3.	Strongly rolling to hilly

Table 17: Description of dependent and independent predictor variables (for description of variables, see Measurement of Variables section)

Model of Moose Utilization

Theoretically, the utilization model can take the form of utilization = f(a,b,c), where the predictors a, b, and c are any combination of the variables tested (Table 16). However, only 3 variables contributed to the predictive power of the model: harassment, cutblock size and dispersion index. Considered individually, all other predictors explained less than 1 percent of the variation of the dependent variable (Eta^2).[1] Of the predictors in the model, harassment followed by cutblock size and dispersion index proved to be the ranked order in terms of Eta^2, with percent values of 20.3, 19.8 and 13.0, respectively (Table 18). Collectively, the model accounted for 44 percent of the variance (unadjusted) and 35 percent (adjusted).

The form of relationships between dependent and independent variables can be examined via the means of predictor subgroups (Figure 18). Moose utilization, as differentiated by harassment categories, displayed a near-linear decrease in stocking percent from low to high, with a range in mean values from 3.5 to 12.8. With respect to cutblock size, peak utilization occurred in the 41-80 acre class, with slightly lower use in larger blocks and

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[1] Eta^2 is a correlation ratio and indicates the proportion of total sum of squares explainable by a predictor. Reference: Andrews, F.M., J.N. Morgan, J.A. Sonquist and L. Klem. 1973. Multiple classification analysis. Institute for Social Research, Univ. Michigan, Ann Arbor, Mich. 105 pp.

MCA Model for Moose Utilization	
Predictor	Eta² (unadjusted)
Harassment	.203b
Block size	.198b
Dispersion index	.130a
R^2 (unadjusted) = .44	R^2 (adjusted) = .35b

MCA Model for Deer Utilization	
Predictor	Eta² (unadjusted)
Block size	.095a
Dispersion index	.082
Site treatment	.057a
R^2 (unadjusted) = .30	R^2 (adjusted) = .21b

Additional Variables Tested in MCA Model for Deer Utilization	
Predictor	Eta² (Unadjusted)
Edge/unit area	.117a
Topography	.065

Table 18: Results of MCA analysis. Values followed by an 'a' are significant at P <.10 and values followed by a 'b' are highly significant (P <.01)

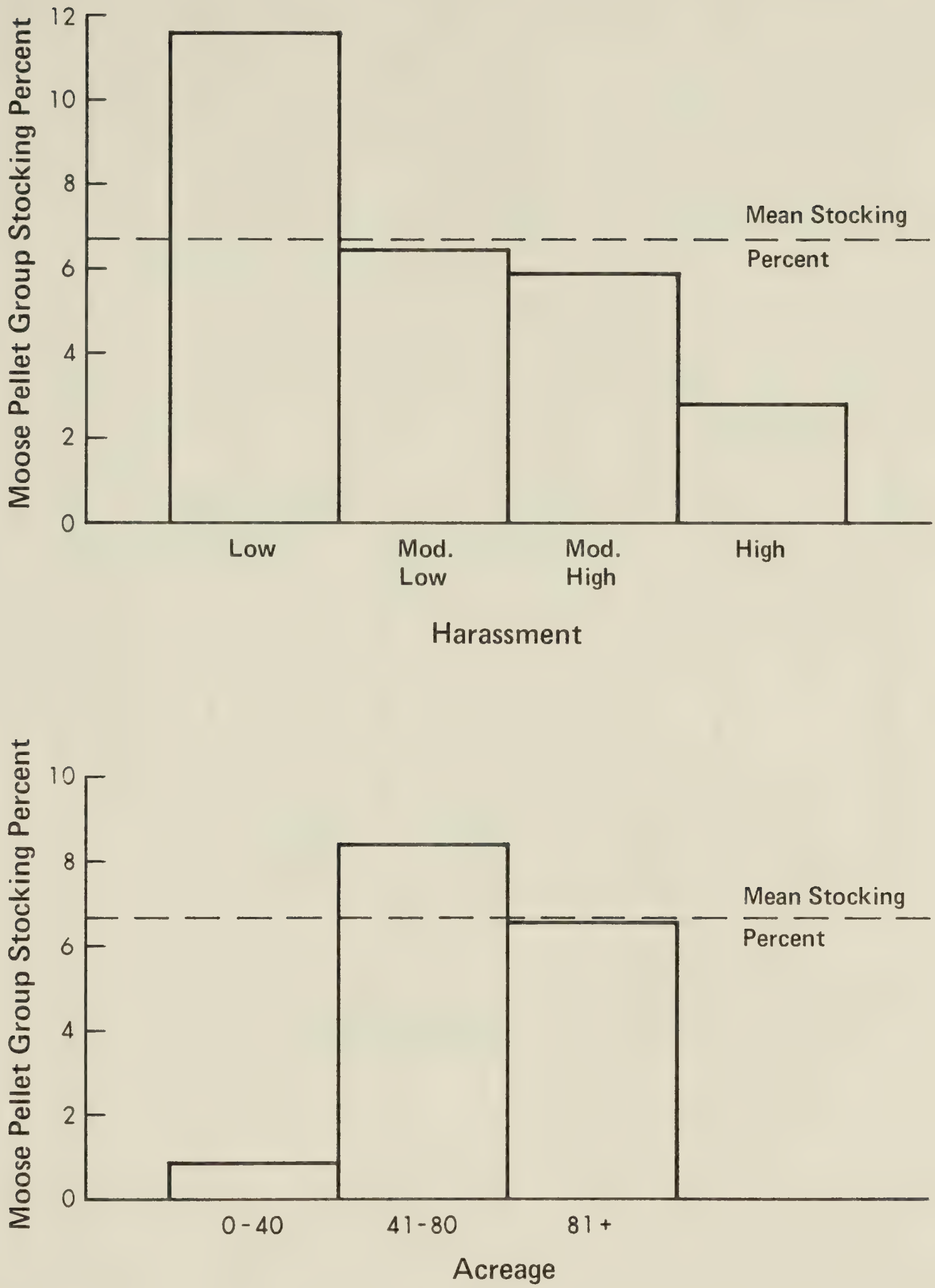


Figure 18: Subclass values for moose predictor variables. Subclass values are adjusted means

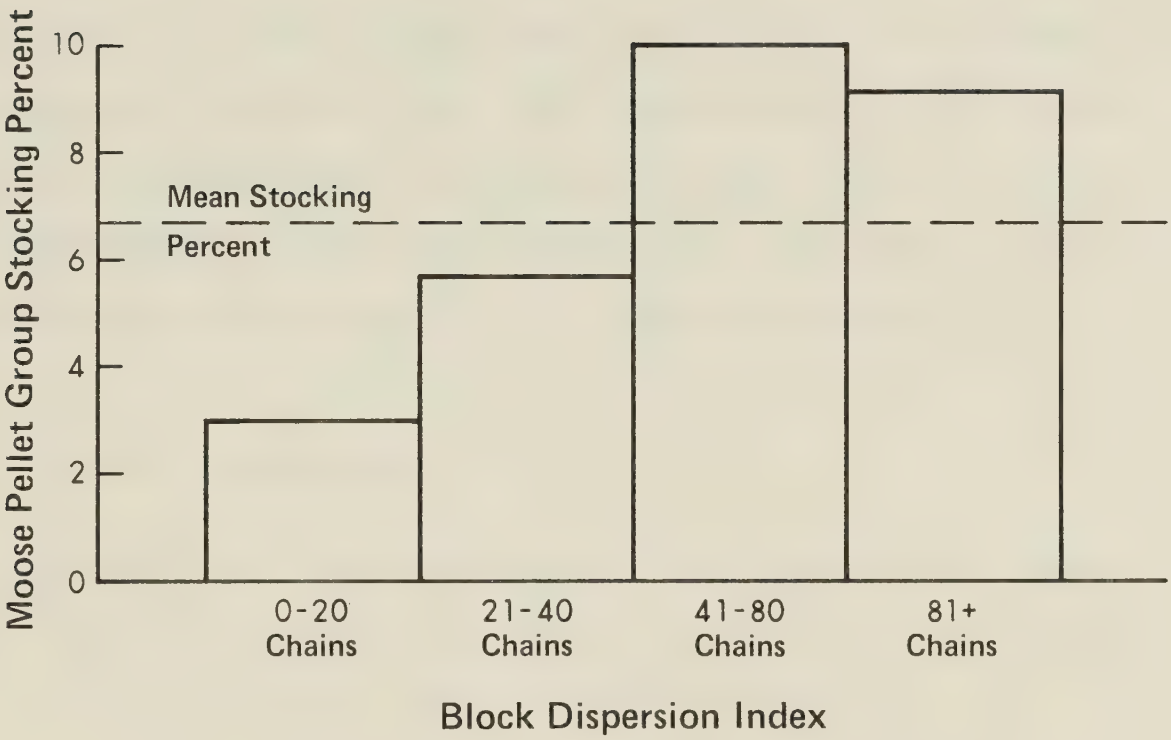


Figure 18: (cont): Subclass values for moose predictor variables. Subclass values are adjusted means

substantially lower in cutblocks 1-40 acres. The relationship of dispersion index to utilization was also near-linear in a positive manner. Pellet group stocking percent values increased with a greater dispersion of cutblocks, peaking at an index of 41-80 chains, and declining slightly thereafter.

The model of moose utilization selected by MCA can be expressed in the functional form of utilization = f(harassment, cutblock size and block dispersion index). Based on the hypothesis of no relationship between predictor and dependent utilization variables, all other predictor variables tested conformed to the null hypothesis.

Model of Deer Utilization

The model for deer utilization was formulated using a 3-way combination of 5 predictors: utilization = f(cutblock size, dispersion index, site treatment, edge per unit area and topography). All other predictors proved insignificant or of limited value in explaining the variance of deer utilization.

Based on multiple correlation coefficients (R^2), the selected model took the functional form of utilization = f(cutblock size, dispersion index and site treatment). It should be noted that dispersion index per se was not a significant predictor. However, the above combination of variables was optimal in terms of the predictive power of

the model. The multiple correlation coefficient of the model was 30 percent (unadjusted) and 21 percent (adjusted). Individual predictive values for cutblock size, dispersion index and site treatment were 9.5, 8.2 and 5.7 percent, respectively (Table 18).

Further examination of predictor subgroups reveal general consistent trends in the form of relationships (Figure 19). Deer utilization peaked in the smallest cutblock size category, 1-40 acres, and declined sharply with increasing acreages. A range in pellet group stocking percent of 14.0 to 3.0 differentiated utilization levels from the smallest to largest size (81+ acres) categories. Increasing the dispersion of cutblocks or forest openings also resulted in a consistent increase in total deer use. The increased use trend was particularly evident when the dispersion index exceeded 80 chains, representing an average linear distance of 20+ chains to the nearest 4 cutblocks from a sample cutblock. With respect to site treatment, scarified and/or burned blocks were utilized more extensively by deer versus untreated blocks. Average utilization levels for treated blocks exceeded twice that for untreated cutblocks.

The two remaining variables, edge per unit area and topography, were tested on an individual basis by substitution into the above model. Deer response to increasing values of cutblock edges was positive in a near-linear fashion, with utilization peaking in cutblocks where

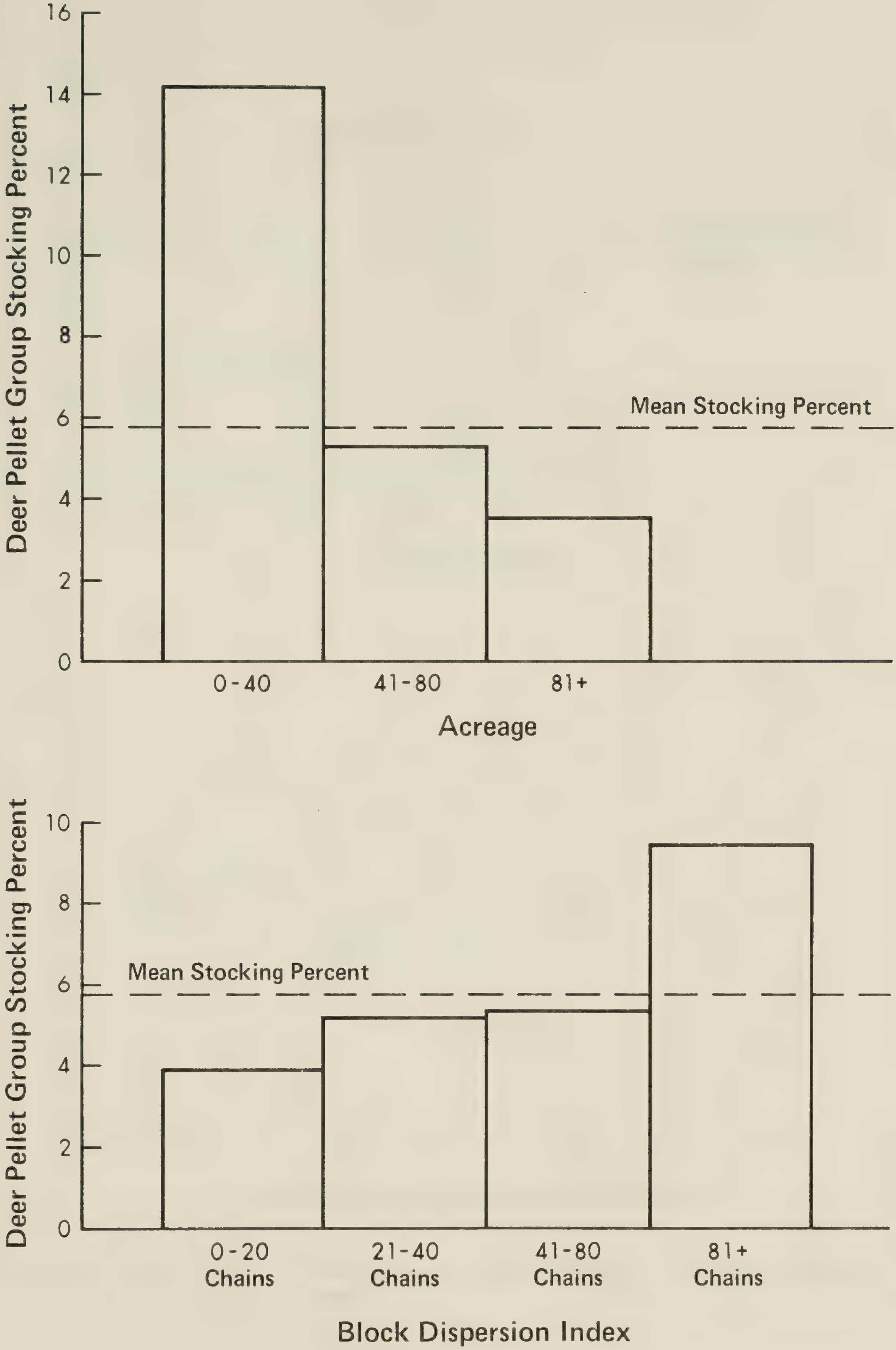
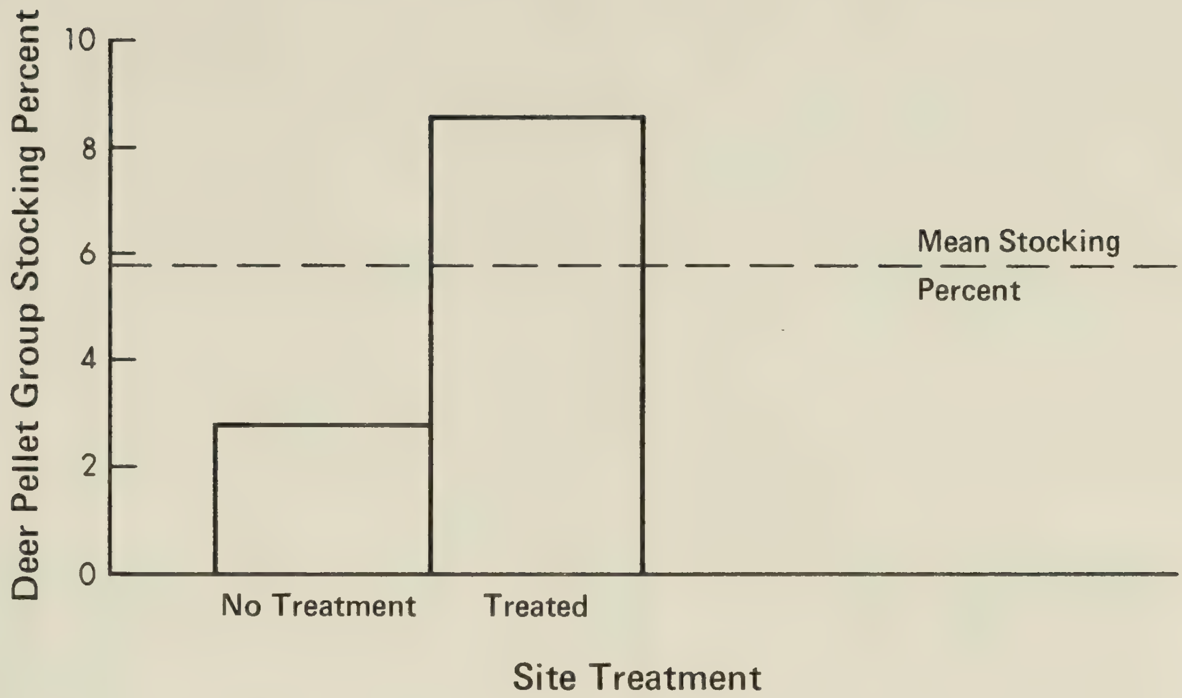


Figure 19: Subclass values for deer predictor variables. Subclass values are adjusted means



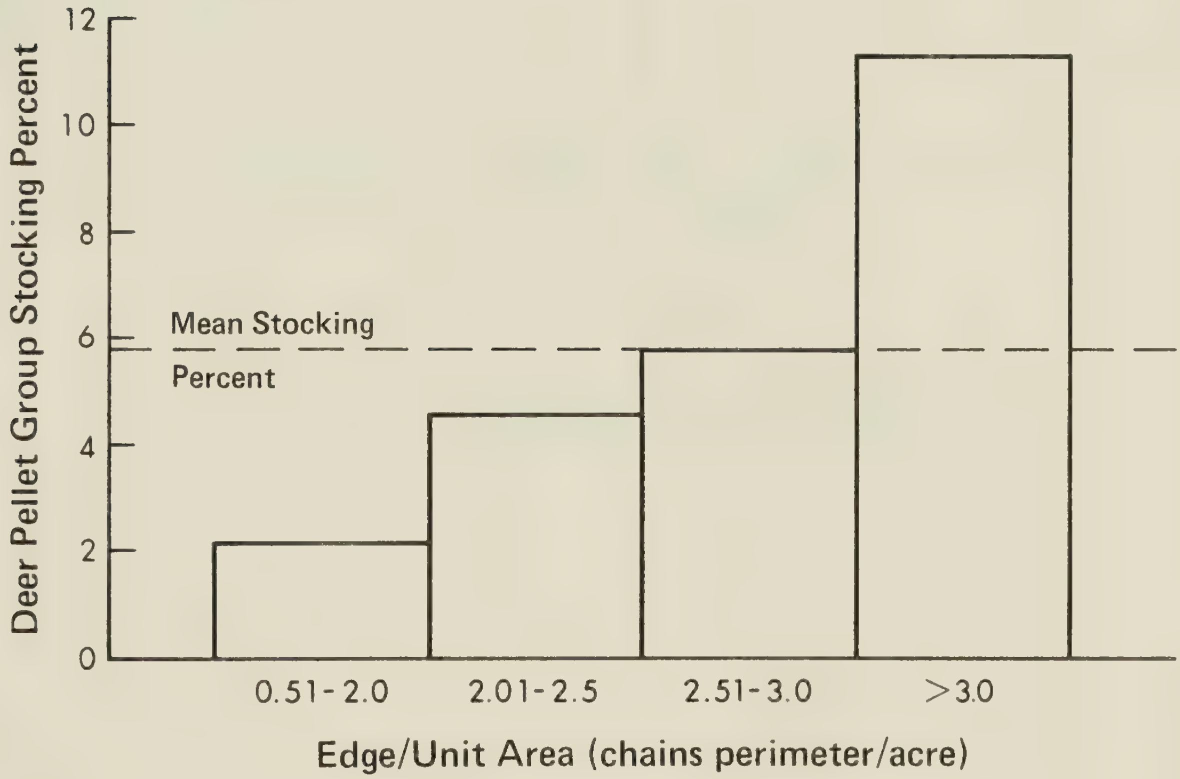


Figure 19: (cont): Subclass values for deer predictor variables. Subclass values are adjusted means

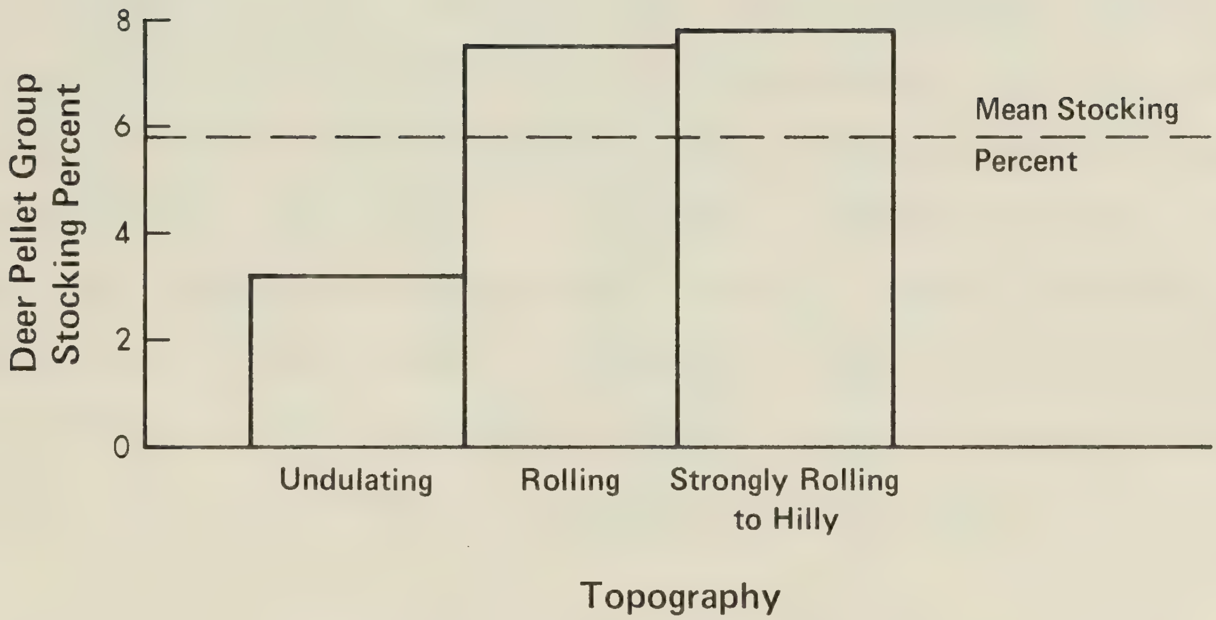


Figure 19 (cont): Subclass values for deer predictor variables. Subclass values are adjusted means

chains of edge perimeter per acre exceeded 3.0 (Figure 19). The value of Eta^2 (12 percent) indicated the relatively strong relationship of the predictor to deer use. Edge per unit area, in fact, proved more effective than all other predictors in this regard. Resulting multiple correlation coefficients (R^2) were, however, lower when the predictor was substituted into the above model.

Topography, with an Eta^2 value of 6.5 percent, was less effective and not significant as an individual predictor of deer use. The form of relationship of predictor subgroups was also less definitive. Noticeable differences in use occurred only between undulating and more rugged topography. Cutblocks in the latter categories were utilized more intensively, with stocking percent levels approximately double that of cutblocks in undulating topography.

Browse Survey Data Compilation

Browse utilization patterns were compiled for combined clearcut blocks and partial cut areas. Since forage characteristics were not significant in influencing ungulate distribution patterns (MCA analysis), the data were not subjected to statistical analysis and are presented for information purposes.

A total of 23 shrub species were tallied during the survey of clearcuts and partial cuts. Included in this total are 17 deciduous and 6 coniferous species. The compiled

results indicate trends in browsing as a function of availability (percent density) and preference (percent of twigs browsed). Contribution to diet (percent) was calculated from the derived utilization factors of individual browse species (Tables 19 and 20).

It should be noted that the survey encompassed a range of cutblock successional stages and different site treatments over an extensive geographic area. The compiled results, therefore, may not be indicative of local range conditions or specific cutblocks.

Shrub Species	Average Density (%)	Average Browsing (%)	Utilization Factors	Contribution to Diet (%)
Deciduous:				
Balsam poplar	0.29	5.91	1.69	2.64
Birch sp.	0.23	2.13	0.50	0.78
Buffalo-berry	0.16	2.95	0.47	0.74
Green alder	2.62	2.17	5.69	8.90
Green mountain ash	0.16	23.27	3.73	5.83
Honeysuckle sp.	1.34	0.31	0.42	0.65
Labrador tea	1.37	0.00	0.00	0.00
Low-bush cranberry	0.71	4.65	3.30	5.17
Raspberry sp.	6.72	0.07	0.45	0.70
Red-osier dogwood	1.94	1.69	3.28	5.13
Ribes sp.	1.86	0.00	0.00	0.00
Rose sp.	5.74	0.33	1.90	2.97
Saskatoon	0.26	15.69	4.10	6.42
Trembling aspen	2.62	5.19	13.61	21.28
Vaccinium sp.	0.27	0.00	0.00	0.00
Willow sp.	1.74	14.03	24.42	38.19
Coniferous:				
Balsam fir	2.05	0.19	0.39	0.61
Black spruce	0.14	0.00	0.00	0.00
Creeping juniper	0.01	0.00	0.00	0.00
Tamarack	trace	0.00	0.00	0.00
Lodgepole pine	0.25	0.00	0.00	0.00
White spruce	0.48	0.00	0.00	0.00

Table 19: Shrub utilization data for clearcuts. Scientific reference names are listed in Appendix 1

Shrub Species	Average Density (%)	Average Browsing (%)	Utilization Factors	Contribution to Diet (%)
Deciduous:				
Balsam poplar	0.72	0.83	0.60	1.49
Birch sp.	0.90	4.46	4.02	10.02
Buffalo-berry	0.31	0.00	0.00	0.00
Green alder	2.37	0.88	2.08	5.20
Green mountain ash	0.08	15.00	1.17	2.93
Honeysuckle sp.	2.57	0.71	1.81	4.52
Labrador tea	2.18	0.00	0.00	0.00
Low-bush cranberry	0.04	20.00	0.81	2.01
Raspberry sp.	6.02	0.03	0.15	0.38
Red-osier dogwood	2.09	3.61	7.55	18.84
Ribes sp.	2.12	0.00	0.00	0.00
Rose sp.	3.92	0.45	1.78	4.45
Saskatoon	0.11	1.00	0.11	0.28
Shrubby cinquefoil	0.62	1.59	0.98	2.45
Trembling aspen	1.52	1.88	2.86	7.14
Vaccinium sp.	0.13	0.00	0.00	0.00
Willow sp.	2.44	6.63	16.15	40.30
Coniferous:				
Balsam fir	0.11	0.00	0.00	0.00
Black spruce	0.05	0.00	0.00	0.00
White spruce	0.02	0.00	0.00	0.00

Table 20: Shrub utilization data for partial cuts. Scientific reference names are listed in Appendix 1

CHAPTER IV

DISCUSSION

It is well established that logging practices have a major impact on the characteristics and balance of wildlife range in North America (Lyon 1966, Pengelly 1963). Yet, little research has been directed at the occupational patterns of wild ungulates in logged areas (Hudson 1976). Effective utilization of habitat depends, in part, on the completeness of habitat use and the subsquent ability of animals to match assimilated energy with requirements.

Utilization by distance from cover and total cutblock use provide indices to the pattern and completeness of cutblock use. Trends established can then be related to the physical features of logged areas, harassment effects and the social and habitat use behavior of affected species.

Utilization Patterns on Clearcuts

Trends in distance from cover were significantly different among ungulate species. For deer, a strong preference for cutblock peripheries characterized the habitat use strategy of the species. Use declined sharply at 5 chains from cover, and was marginal beyond 6 chains (Figures 4 and 8). This trend suggests cutblock widths of 8-10 chains are maximum for effective exploitation by deer.

Comparable studies indicate similar patterns of high peripheral use, although distance from cover curves vary. Reynolds (1962,1966) observed deer use of natural openings in ponderosa pine and spruce-fir forest types in Arizona. Preference for edges was characteristic of deer use in both forest types. Utilization of openings in the ponderosa pine forest extended to 1,100 feet (16.7 chains) from cover, with reduced use of medial areas beyond 700 feet (10.6 chains). By comparison, utilization of openings in the spruce-fir forest declined to subaverage at 450 feet (6.8 chains). Other authors have also implied the preference of deer for cutblock edges. Wallmo (1969) reported optimal cutblock widths of 3 chains and Telfer (1970) recommended widths of 200 feet (3.0 chains) for maximum browse utilization.

The general pattern of deer activity on cutblocks appears related to the habitat use behavior of the species. Deer are characterized as animals of habitat 'edges', requiring a diverse range balance (Gill 1957b, Telfer 1974). Food and cover requirements must be met within a small, usually well-defined cruising radius. Home range sizes have been estimated by McGinnes (1969) at 1 square mile, or .5 to 1 mile in diameter (Taber 1973). Because of the habitat use strategy of the species, large homogeneous areas are generally unsuitable as habitat.

Cutblock utilization by moose was comparatively uniform, with a relatively high level of activity recorded at 8 chains from cover (Figure 8). While the above figure

was the greatest distance category evaluated, it does not necessarily represent the upper limit in cutblock utilization. The pellet group stocking percent curve was in fact, increasing at this point. Since the 8-chain category also encompassed sample points at greater distances, it may be assumed that relatively consistent utilization levels would continue beyond 8 chains from cover. From a management perspective, cutblock widths of 16 to possibly 20 chains, or greater, would be compatible with the habitat use behavior of moose.

No comparable studies were found in the literature, although there are suggestions of the above patterns of cutblock use. Irwin (1975), for example, reported moose were effective colonizers of large burns, while Peek et al. (1976) suggested a cutblock size of 80 hectares (198 acres) as characteristic of prime moose range in Minnesota. Comparably, Telfer (1974) suggested moose range may be balanced with larger clearcuts, up to .5 square miles in size.

The distance from cover curve for elk was generally similar to that for deer (Figure 8). However, peak utilization by elk occurred at cutblock edges, whereas deer utilization peaked within cover. Decline in elk utilization with increasing distance from cover was pronounced at 4-5 chains, suggesting optimal cutblock widths of 8-10 chains.

Comparable studies indicate variations in distance from cover trends. Harper (1970) found elk use maximum at

cutblock edges and sharply reduced beyond 300 yards (13.6 chains). Harper (1971) also recommended cutblock widths of 200 yards (9.1 chains) or less. Reynolds (1962,1966) observed the use of natural openings in spruce-fir and ponderosa pine forests in Arizona. Elk use in both habitats peaked beyond opening peripheries, but zones of maximal use and extent of medial use differed. Utilization of openings in the spruce-fir type maximized at 100-200 feet (1.5-3.0 chains) and declined to nil at 600 feet (9.1 chains). Utilization of openings in the latter type peaked at 300-400 feet (4.5-6.1 chains) and extended to 1100 feet (16.7 chains), the farthest distance sampled.

The pellet group stocking percent curves for moose, deer and elk did not isolate the effects of harassment. Harassment did exert a significant effect by species in the degree or intensity of total cutblock use.

Moose densities (stocking percent) were markedly higher in low harassment areas (Figures 5 and 9). Although emigration to low harassment areas is a possible explanation, observations by Goddard (1970) refute this theory. No directional tendancy from heavily hunted to lightly hunted areas was reported in the above study, with adult moose sedentary in both summer and winter habitats. Assuming equivalent range conditions, the disparity in moose utilization levels may be related to the impact of harassment, particularly hunting pressure. Prescott (1974) noted the historical decline of moose populations with

encroaching human settlement, and attributed hunting as a major factor.

The preference of moose for relatively large open foraging areas would presumably contribute to hunting vulnerability. Prescott (1974) also suggested that moose do not exhibit the degree of behavioral plasticity necessary to adapt to the activities of man. The impact of hunting would therefore be greater in areas of limited cover and good access. By comparison, the characteristic low-density habitat-occupancy pattern of the species, coupled with a solitary social organization and large home range size, would tend to mitigate the impact of harassment in remote areas (Houston 1974). Longhurst (1957), for example, reported that inaccessibility was a major reason for failing to achieve moose population control in many parts of Canada.

Compiled utilization levels for deer indicate a reversal of the trend established for moose, with a greater intensity of use for cutblocks in the high harassment category (Figures 5 and 9). This apparent anomaly is, however, consistent with historical population trends in North America. Human settlement and land use practices have consistently favoured deer, particularly white-tailed deer, over other species (Prescott 1974). Its apparent success in proximity to the activities of man relate to behavioral adaptability, as well as creation of favourable habitat (Taber 1966). Deer 'learn' and adjust behavioral patterns to disturbances, particularly those of regular occurrence

(Behrend and Lubeck 1968, Dorrance et al. 1975).

The results of the present study and related observations in the literature indicate that the overall adverse effects of timber harvesting via the harassment pathway are marginal. Exceptions to this generalization could, however, occur with specific conditions on a local basis, for example, concentrations of deer in poor condition (Moen 1976).

Elk response to harassment was parallel to deer in that high harassment cutblocks sustained heavier use (Figure 9). The significance of this relationship, however, proved difficult to evaluate. Since only portions of the Rocky-Clearwater Forest had relatively large resident populations, suitable sampling areas were limited.[1] Many of the cutblocks utilized by elk were of the intermediate harassment classification and did not offer distinct contrasts in harassment. The gregarious feeding behavior of the species may also have contributed to observed results. Heavy utilization of moderately high or high harassment cutblocks could have occurred within a relatively short time span when harassment sources were at a minimum.

One other factor should be noted for interpretation of results. In the Rocky-Clearwater Forest, heavy utilization of moderately-high and high harassment cutblocks was recorded in management unit R9L18; an area that also

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[1] Reference figures are contained in Appendix 2.

coincided with a Provincial Wildlife habitat improvement project. The Moose Creek study area was seeded to exotic legumes and grasses to improve range suitability. Added attractiveness of the cutblocks as foraging areas could have biased results.

No definable conclusions regarding elk-harassment interactions can be drawn from the present study, except perhaps the need for further research. To date, studies on the response of elk to potential harassment sources are also inconclusive. Ward _et al._ (1973) and Schultz and Bailey (1978) reported that the species was adaptable to such disturbances as recreational activities and highway traffic. Stelfox (1972) and Dealy (1975), however, postulated that harassment was an important factor in causing elk to shun clearcuts, and Lyon (1975) observed that even low-quality forestry roads caused avoidance responses unless heavy cover was present.

There is general agreement on the importance of cover to accommodate the habitat use and social behavior of elk (Black _et al._ 1976, Stelfox 1972). It is this requirement that perhaps has more bearing on the occupational patterns of the species in logged areas than harassment sources per se (Lyon 1975).

Relative Use Trends on Clearcuts

Analysis of variance failed to detect significant differences in total cutblock use attributable to harassment as a main effect because of significant harassment x species interactions. Similarly, the impact of harassment on distance from cover trends was not apparent for the combined cutblock use strategies of moose, deer and elk.

Relative use curves contrasting intraspecific trends by harassment category did reveal a significant effect on moose utilization in high harassment cutblocks (Figure 11). Previous utilization curves established by stocking percent figures suggested that a minimum cutblock width of 16 chains was compatible with the habitat use behavior of moose. However, the relative use curves indicate that this guideline is applicable only to low harassment cutblocks. High harassment utilization was pronounced at cutblock edges and declined to subaverage beyond 3-4 chains, suggesting optimal widths of 6-8 chains.

The deviation in utilization patterns from low to high harassment cutblocks indicates a shift to greater dependence on cover in habitat use. Implications for integrated management suggest an increased priority on habitat cover, both to reduce the impact of harassment, and to accommodate altered cutblock use behavioral patterns.

Deer displayed similar utilization patterns for both harassment categories, deviating significantly from uniform

use (Figure 12). The consistency in these curves may reflect the strong habitat preferences and habitat use behavior of deer (Pengelly 1963). Compared to low harassment effects, occupancy patterns on high harassment cutblocks were not appreciably altered beyond block edges.

Relative use trends for elk were analagous to deer in that both harassment categories deviated significantly from uniform use by similar response curves. As outlined previously, the validity of harassment categorization and sampling areas for elk in the present study was questionable. Peripheral use of cutblocks was, however, more pronounced for the high harassment category (Figure 13).

Relative use curves determined by shrub utilization indicated different patterns by harassment category (Figure 14). Foraging activity in low harassment cutblocks conformed to expected or uniform use. By comparison, approximately two-thirds of total shrub browsing in the high harassment category occurred within 3 chains of cover.

The individual contribution of moose, deer and elk to the above curves is not indicated. For high harassment cutblocks, the shrub utilization curve, however, corroborated pellet group relative use curves for all three ungulate species. For the low harassment category, the shrub utilization curve conformed most closely to the relative use pattern established for moose. Given the preference of moose for browse, and the comparatively large forage requirements, it may be expected that the species exerts a greater impact

on the browse resource than deer or elk (Stelfox and Taber 1969, Telfer 1974). Shub utilization results do, however, indicate that low harassment cutblocks up to a minimum width of 16 chains (8 chains from cover) are uniformly exploited by the combined habitat use strategies of moose, deer and elk.

Utilization Patterns on Partial Cuts

Available cover on the partial cuts sampled apparently met security requirements for moose and deer and simultaneously proved attractive as foraging habitat. Relative use curves based on pellet group stocking percent conformed to expected or uniform use up to 17 chains from cover; the greatest distance category evaluated (Figure 15).

Little quantitative information is available describing security cover requirements for moose. Irwin (1975) and Telfer (1974), however, report that the species is adaptable to a variety of habitat conditions, including sparse cover.

Black et al. (1976) outlined more specific cover requirements for deer and elk. For the latter species, security cover was defined as vegetation capable of hiding 90 percent of an animal at a distance 200 feet or less, with deer requirements less stringent.

Field observations of partial cuts indicated that visual line-of-sight distances approximated, or were less than, the above specifications. While deer activity did not

deviate significantly from uniform use, elk utilization was confined to a narrow peripheral zone (Figure 15).

The limited utilization of partial cuts by elk may be related to range characteristics. Elk are typified as grazers, and require open forage areas to accommodate habitat use behavior (Stevens 1974). Edgerton (1972) observed the preference of elk for clearcuts over partial cuts, and attributed the lack of preferred forbs and grasses in the latter for the disparity in use.

The pattern of shrub utilization in partial cuts (Figure 16) supported relative use trends determined from pellet group data for moose and deer. Individual partial cuts also exhibited near-parallel use curves, indicating similar occupational patterns in different partial cuts over a geographic expanse (Figure 17).

From a management perspective, results indicate that large partial cuts meet summer range requirements for moose and deer. It should be noted, however, that summer requirements are considerably more flexible than winter requirements, particularly for white-tailed deer (Gill 1957a, Telfer 1974).

Models of Cutblock Utilization

Moose Utilization

Prediction of moose utilization of clearcut blocks was

definable by only three of the predictors tested. Two of the predictors, dispersion of cutblocks and block size, relate directly to the pattern of timber harvesting. Harassment is commonly an associated indirect effect.

Previous analysis disclosed significant differences in the effect of harassment by species, and in the pattern of cutblock utilization by moose. The MCA model corroborated the above results, and also indicated the relative importance of the predictor. Harassment, by itself, explained more of the variation in moose utilization than any other variable (Table 18). From a management perspective, results suggest that harassment factors may preempt other habitat considerations in the level and pattern of high-harassment cutblock use.

The correlation of cutblock size and moose utilization levels indicate that foraging areas are an important component of range balance (Table 18). Edge per unit area, for example, was not effective in explaining moose utilization levels, whereas cutblock size was. The significance of foraging areas was also noted by Peek et al. (1976) and Telfer (1978). Both reports further suggested that moose range can be balanced with large size clearcuts (80+ acres).

The preference of moose for larger cutblocks adds an extra dimension of flexibility to integrated forest management planning. A tolerance for increased cutblock widths, coupled with block sizes exceeding 80 acres (Figure

18), would allow considerable variability in the design and pattern of cutting units.

Trends associated with the block dispersion index do, however, indicate a negative utilization response to clumped patterns of cutblocks (Figure 18). Many of the cutblocks at the lower scale of the index were laid out in a checkerboard fashion. Subsequent logging often failed to preserve buffers between blocks, creating in effect, large cutblocks with long visual line-of-sight distances and isloated stands of cover. Such logging patterns may enhance potential harassment effects, particularly in high harassment areas (Dealy 1975).

The lack of correlation between utilization and site treatment, cover and the remaining habitat diversity variables (Table 16) may be due, in part, to the flexible habitat requirements of the species. No definite pattern in moose utilization could be attributed to any of the above predictors.

Variables describing forage characteristics similarly exhibited poor correlations. These predictors were categorized on the basis of differences in plant cover density by cutblock. With the relatively low moose densities observed in the study area, these differences in forage availability may have been incidental to moose requirements. Comparably, no variation in utilization was attributable to number of years after logging; a variable highly correlated to the availability of forage (Taber 1973).

Deer Utilization

Deer utilization analysis involved more predictors with significance in comparison to the moose model. Resulting correlation coefficients were, however, lower. This difference in results may be due, in part, to the distributional pattern of deer. Compared to moose, the species tends to be more exacting in habitat requirements and subsequently, exhibits greater variation in local densities (Houston 1974, McCaffery and Creed 1969). Habitat occupancy may also reflect traditional patterns of use that are not directly related to present habitat conditions (Pengelly 1963).

Two of the three predictors used in model formulation expressed habitat diversity. Acreage and block dispersion index categorized the size and pattern of forage and cover-producing components of deer range. The third predictor, site treatment, described habitat alterations to cutblocks in terms of scarification and/or burning, or none-treatment.

Deer preference for smaller forest openings (Figure 19) was consistent with previous analysis indicating high peripheral use of cutblocks. Home range size, in addition to habitat use behavior, has been postulated as a determining factor in the intensity of cutblock use as related to size (Dealy 1975, Taber 1973). Assuming a cutting unit will only affect animals within a hypothetical home range area, a single large cut would create an unfavourable range balance

and reduce the potential numbers of animals capable of exploiting that cutblock.

Opening size classes and associated utilization patterns established by the MCA model are in general agreement with comparable studies. Reynolds (1966) noted extensive use of openings less than 20 acres, while Patton (1974) found forest openings up to 32 acres extensively utilized by deer. Verme (1965) suggested, as a management guideline, cutblocks exceeding 40 acres to prevent serious damage to forest plantations by deer. From a management perspective, comparable studies and present results indicate cutblocks up to 40 acres are compatible with deer range (Figure 19).

The positive correlation of the block dispersion index with deer utilization (Figure 19) again illustrates the importance of adequate cover well-dispersed through deer range (Telfer 1974). The proximity of forage and cover-producing habitat is often a limiting factor in range suitability, particularly in winter (Gill 1957a).

Utilization peaked in the highest dispersion index category, representing a minimum average distance of over 20 chains to each of the next 4 forest openings from a cutblock. This interspersion pattern would provide ample cover for deer and also include cutblocks as foraging areas within home range territory. Decreased use at the lower end of the scale may reflect a paucity of cover resulting from a clumped pattern of cutblocks.

Results suggest that cutblocks would have to be well-spaced (minimum 20 chains between blocks) to encourage a large positive response in deer utilization (Figure 19). This pattern of logging may, however, be impractical for timber management purposes where an initial 50 percent volume removal through a cutting area is allowed (Henderson 1977). Maintenance of a minimum 5 chain buffer between blocks should, however, result in a positive utilization response similar to the pattern indicated by the MCA model (Figure 19).

Correlation of the site treatment predictor with utilization indicates a higher level of use on scarified and burned cutblocks. A review of the literature suggests possible pathways involved in this relationship are barriers and corridors, and habitat alteration as manifested by changes in forage quality and species composition.

Logging slash and debris has the potential effect of restricting access and modifying distributional activity (Pengelly 1963). Restriction of access generally tends to be most limiting where forest residues are evenly distributed (Garrison and Smith 1974). Heavy burning and particularly, scarification, provide potential access and/or access corridors.

Little information is available quantifying the volume and arrangement of forest residues which constitute a barrier. Related empirical observations do, however, corroborate the above observations. Gockerell (1966) noted

that deer damage to forest regeneration was more severe in heavily-burned blocks, while Walker et al. (1971) speculated that randomized feeding activity permitted by clean-burning resulted in a similar situation. Walker et al. (1971) also noted that scarification concentrated foraging activity on scarified strips.

Previous analysis indicated that forage availability predictors were not significant in explaining variations in deer utilization. Site treatment practices do, however, have additional effects on forage characteristics which may increase range attractiveness to deer.

Scarification and burning have an initial impact of retarding shrubby growth and increasing the composition and variety of herbaceous species (Stelfox and Cormack 1962). Herbaceous vegetation forms an important component of dietary intake during the summer months (Skinner and Telfer 1974). Burning also has the effect of increasing forage palatability through added nutritive content (Taber 1973).

The remaining predictors, edge per unit area and topography, were analyzed as individual habitat parameters outside the context of the model. Note that topography was not significant in the analysis and is presented more for information purposes and as a contributing variable in explaining deer habitat use.

The strong positive correlation of cutblock utilization to edge per unit area (Figure 19) supports the evidence that deer are animals of habitat edges. For species that are

dependent upon habitat diversity, the extent of habitat edge, or cutblock size and shape, provides an index to range suitability (Telfer 1974). An additional effect of cutblock shape is through number of home ranges affected. McGinnes (1969) hypothesized that configurations deviating from square or circular would contact more home ranges and subsequently, number of animals.

From a management perspective, maximization of cutblock perimeter would improve deer habitat. The strong relationship of the predictor to utilization also indicates that consideration of habitat edge per se would be an effective management strategy.

The form of the relationship of topography to total utilization again relates to habitat diversity. Higher levels of use were sustained in cutblocks situated on rougher topography (Figure 19). Areas of topographic variation are generally indicative of superior habitat for ungulate species dependent on range diversity (Stelfox and Taber 1969). Topographic variation may also provide feeding security on clearcut blocks, particularly at greater distances from cover.

With respect to logging practices, the potential impact on deer habitat in areas of topographic variation can be expected to be more sensitive to both detrimental and beneficial effects. Because a diverse habitat exists prior to logging, the possibility of upsetting range balance is greater in comparison to homogeneous areas (Telfer 1970).

The potential for maximum sustained use would, however, also be greater, particularly when attention is focused on range balance.

Browse Survey Results

A noteworthy observation of compiled shrub utilization data (Tables 19 and 20) is the general low degree of browsing. The highest average percent browsed (23.3 percent) was recorded for green mountain ash. Assuming a safe 60 percent utilization level (Telfer and Scotter 1975), the above figure, and associated lower values for remaining species, indicates little browse competition and range use below sustained carrying-capacity. This observation supports previous MCA analysis where no significance was found due to forage availability predictors.

Important browse species, as indicated by contribution to diet, were similar for both partial and clearcut areas. Willow was the dominant browse species and accounted for approximately 40 percent of browse consumption. Other important browse species included balsam poplar, trembling aspen, red-osier dogwood, birch, green alder, low-bush cranberry, green mountain ash and rose. Saskatoon and green mountain ash, while highly preferred, were restricted in importance by general low availability. In contrast, the ubiquitous distribution of green alder and rose formed an important food source, despite low preference. A high

density of honeysuckle and shrubby cinquefoil on partial cuts created a similar situation.

Observed results are in general agreement with reported food habits in other areas, particularly for key browse species. Willow, trembling aspen, balsam poplar, red-osier dogwood and birch are commonly listed, with considerable overlap of diets for moose, deer and elk (Prescott 1974, Stevens 1974).

CHAPTER V

SUMMARY AND CONCLUSIONS

Conclusions

The conclusions of the study are presented in reference to hypotheses formulated and tested. A brief summary of range survey results is also presented in this section.

The hypothesis of no effect by harassment on total cutblock use was supported for the combined occupancy patterns of moose, deer and elk. The interaction of species by harassment category was, however, significant. Total cutblock moose utilization was higher in low harassment cutblocks versus high harassment areas. Deer utilization trends reversed the pattern exhibited by moose.

Distance from cover exerted a significant effect on cutblock utilization patterns for combined ungulate use. Also refuted was the hypothesis of no difference by species in cutblock utilization trends. Moose utilization over distance from cover was consistently more uniform compared to deer and elk. The latter two species exhibited a strong preference for cutblock peripheries.

Harassment was not a significant factor in the distance from cover utilization patterns for the combined cutblock use patterns of moose, deer and elk. Subsequent relative use analysis, however, disproved the hypothesis of no effect by

harassment on distance from cover use patterns for moose. Utilization of low harassment areas did not deviate significantly from uniform or expected use, in contrast to use patterns on high harassment cutblocks. Deer utilization trends were significantly different from the uniform use curve for both harassment categories, implying no effect attributable to harassment. Although similar trends were observed for elk, no definite conclusion could be made.

The effect of harassment and distance from cover were not different by geographic region, implying a consistent effect of these factors throughout the study area.

The hypothesis that utilization by distance from cover does not deviate from uniform or expected use in partial cuts was supported for moose and deer. The elk utilization curve, however, was upwardly skewed at cutblock edges.

In cutblock utilization analysis, the hypothesis of no relationship between moose utilization and independent variables was supported for edge per unit area, topography, site treatment, year of cut, forage characteristics and cover. The model of utilization = f(harassment, block dispersion index and block size) was significantly correlated with moose utilization. The predictors in the above model were also significant on an individual basis.

For deer, the hypothesis of no relationship held true for harassment, year of cut, forage characteristics and cover. The model of utilization = f(block size, block dispersion index and site treatment) was significantly

correlated with cutblock utilization, as well as the individual predictors of block size, site treatment and edge per unit area. Topography and block dispersion index, while not significant, exhibited definitive relationships with deer utilization of cutblocks.

The compiled shrub utilization data indicate that willow, balsam poplar, trembling aspen, red-osier dogwood, birch, green alder, green mountain ash and rose are important browse species. The low level of shrub utilization is also a possible explanation of why forage characteristics were not important in determining cutblock utilization responses by deer and moose.

A Summary of Management Recommendations

The recommendations summarized in this section are based on the major findings of this study, and were developed for operational integrated management. It should be noted, however, that maximal integrated production is not, or should not be, the only considered management objective. As Gill (1957b) points out, there is little justification in actively managing for a wildlife resource where that resource is not fully exploited. According to Gill (1957b), the place for implementation of integrated management is where forestry practices are likely to limit big game populations, and/or the limitation of big game populations limit utilization of the resource. Conversely,

it is possible that certain areas warrant more protection and management than afforded by the following recommendations. Application of guidelines should therefore be consistent with local conditions and management objectives.

Recommended cutblock widths vary for the species under consideration. Widths of 8-10 chains would encourage uniform use of cutblocks by deer and elk. Increased widths (16-20 chains) are compatible with moose range in low harassment areas.

Harassment exerted a significant effect on the cutblock use behavior of moose, and in the degree of total block use. Recommendations in high harassment areas include reduced cutblock widths (6-8 chains) and increased priority on habitat cover. Maintenance of minimum 5 chain buffers between blocks are applicable to both harassment categories.

Although block sizes were not examined by harassment category, distance from cover curves suggest smaller cutblocks in high harassment areas would promote more complete utilization by moose. Large size blocks (80+ acres), coupled with increased cutblock widths, would add to the flexibility of management planning for moose and timber production in low harassment areas.

No appreciable differences in utilization were observed by harassment category for deer and elk. Except for possible local conditions, the impact of this pathway on deer is considered negligible. For elk, comparable studies do,

however, indicate a dependence on heavy cover, particularly in high harassment areas. Black *et al.* (1976) and Lyon (1975) give specific recommendations for mitigating the impact of harassment on elk.

Cutblock sizes for deer are recommended at less than 40 acres with maximization of block perimeters. Maintenance of minimum 5 chain buffers between blocks would improve range balance in both harassment categories.

Results indicated that partial cuts were compatible with the summer range requirements of moose and deer. Wintering areas would, however, require special attention in proposed large cuts, particularly for deer. The recommended logging system for elk is clearcutting to promote forage values for the species.

Extensions of the Present Study

The present study attempted to determine and evaluate the major effects of forestry practices on wild ungulates. Recommendations and guidelines arising from the study are designed to maintain or increase wildlife production within the constraints imposed by timber harvesting.

Implementation of such guidelines are an important first step towards integrated forest management. A logical extension of the study would be the derivation of production functions for the wildlife resource based on the effects of forestry practices. For example, how many annually

harvestable animals can be expected from a certain pattern and size distribution of cutblocks in a low harassment area? Such information would provide forest resource managers with a basis for decision-making and optimizing a socially desirable mix of forest outputs.

Obviously, the formulation of production functions for the wildlife resource requires more information than obtainable from the present study. Further research is required to define and quantify the direct and indirect effects of logging practices on forest conditions which limit or enhance wildlife productivity.

While many of the cause-and-effect relationships of impact assessment have been described, a major gap in knowledge remains in defining the impact of harassment. Some of the limitations involved in evaluating harassment effects were discussed in the present study. Further research is required to (1) define harassment stimuli in terms relevant to animal perception, and (2) define animal responses to harassment sources. Such information is required to predict what level of harassment is equal to what pattern of habitat use, and subsequently, how the harassment pathway fits into production functions for wildlife and timber outputs.

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Scientific Name	Common Names(s)
	Deciduous Species
Alnus crispa (Ait.) Pursh	green alder
Amelanchier alnifolia Nutt.	saskatoon
Betula sp.	birch
B. papyrifera Marsh	paper birch (white birch)
Cornus stolonifera Michx.	red-osier dogwood
Ledum groenlandicum Oeder	Labrador tea
Lonicera sp.	honeysuckle
Populus balsamifera L.	balsam poplar
P. tremuloides Michx.	trembling aspen
Potentilla fruticosa L.	shrubby cinquefoil
Ribes sp.	currant, gooseberry
Rosa sp.	rose
Rubus sp.	raspberry
Salix sp.	willow
Shepherdia canadensis (L.) Nutt.	buffalo-berry
Sorbus scopulina Greene	green mountain ash
Vaccinium sp.	bilberry, blueberry, bog cranberry
Viburnum edule (Michx.) Raf.	low-bush cranberry
	Coniferous Species
Abies balsamea (L.) Mill.	balsam fir
A. lasiocarpa (Hook.) Nutt.	alpine fir
Juniperus horizontalis Moench	creeping juniper
Larix laricina (Du Roi) K. Koch	tamarack
L. lyallii Parl.	alpine larch
Picea engelmannii Parry	Engelmann spruce
P. glauca (Moench) Voss	white spruce
P. mariana (Mill.) BSP.	black spruce
Pinus albicaulis Engelm.	white-bark pine
P. contorta Loudon var. *latifolia* Engelm.	lodgepole pine

APPENDIX 1: List of scientific and common names of plant species. Source: Moss, E.H. 1974. Flora of Alberta. Univ. of Toronto Press. 546 pp.

Cutblock Designation	Legal Description	Year Cut Completed	Acreage Surveyed	Number PLots: Range	Number PLots: Pellet Group	Stocking %: Moose	Stocking %: Deer	Stocking %: Elk	Harassment Category	Dispersion Index	Edge/ Unit Area	Site Treatment	Topography	Vegetation Density %: Forbs	Vegetation Density %: Grasses	Vegetation Density %: Shrubs
W3 L6 1	T64-R10-W5	1968	30	24	48	31.2	16.7	0.0	mod. high	61	3.04	scarified	gen. roll.	22	28	27
W3 L6 3	T64-R10-W5	1967	37	25	49	4.1	6.1	0.0	mod. high	48	2.23	scarified	mod. roll.	52	22	64
W3 L6 6	T64-R10-W5	1973	59	42	83	9.6	14.5	0.0	high	25	2.18	scarified	mod. roll.	34	41	30
W3 L6 9	T64-R10-W5	1970	51	35	69	2.9	4.3	0.0	high	72	1.80	scarified	gen. roll.	30	35	31
W3 L6 19	T64-R10-W5	1969	82	63	126	5.6	7.1	0.0	mod. high	46	2.14	scar&burn	gen. roll.	52	23	29
W3 L6 21	T64-R10-W5	1973	45	30	60	8.3	11.7	0.0	mod. high	51	1.96	scarified	mod. roll.	36	26	15
W3 L6 30	T64-R10-W5	1973	41	29	58	1.7	44.8	0.0	mod. high	98	2.07	scarified	str. roll.	37	22	21
W3 L6 A	T64-R10-W5	1967	31	21	41	7.3	19.5	0.0	high	58	2.58	scarified	mod. roll.	24	35	17
W3 L6 E	T64-R10-W5	1967	25	18	36	16.7	22.2	0.0	mod. high	25	2.80	scarified	str. roll.	26	29	29
W3 L6 H	T64-R10-W5	1967	46	33	66	9.1	3.0	0.0	mod. high	38	2.29	scarified	gen. roll.	59	29	59
W2 L41 2	T66-R14-W5	1968	24	16	32	18.7	3.1	0.0	low	70	2.88	scarified	gen. roll.	35	35	17
W2 L41 3	T66-R14-W5	1969	36	28	55	12.7	5.4	0.0	low	21	2.69	scarified	mod. roll.	66	26	37
W2 L41 4	T66-R14-W5	1969	34	21	42	9.5	2.4	0.0	low	27	2.36	scarified	str. roll.	30	30	13
W2 L41 21&22	T66-R14-W5	1970	102	77	152	11.8	3.3	1.3	low	92	1.87	scarified	hilly	44	33	42
W2 L41 23	T66-R14-W5	1970	33	25	50	32.0	8.0	0.0	low	88	2.92	scarified	str. roll.	24	42	23
W2 L41 24	T66-R14-W5	1970	6	8	16	0.0	43.8	0.0	low	148	4.99	none	mod. roll.	23	55	15
W2 L41 26	T66-R14-W5	1970	54	38	76	14.5	5.3	3.9	mod. low	102	1.86	none	mod. roll.	25	30	10
W2 L41 27	T66-R14-W5	1972	35	27	54	22.2	0.0	0.0	low	100	2.31	none	undulating	25	23	18
W2 L41 28	T66-R14-W5	1972	40	32	64	15.6	3.1	0.0	low	106	2.31	none	mod. roll.	28	15	11
W2 L41 30	T66-R14-W5	1972	23	20	40	30.0	0.0	2.5	low	134	3.02	none	gen. roll.	26	18	13
R6 L12 1	T41-R16-W5	1968	22	18	36	0.0	2.8	50.0	mod. low	107	2.79	none	mod. roll.	18	49	25
R6 L12 2	T41-R16-W5	1970	19	15	30	0.0	0.0	36.7	mod. low	26	2.85	none	hilly	30	38	14
R6 L12 4	T41-R16-W5	1967	20	20	39	0.0	2.6	25.6	mod. low	15	3.40	none	mod. roll.	20	46	17
R6 L12 8	T41-R16-W5	1967	20	19	37	0.0	8.1	13.5	mod. low	19	2.81	none	str. roll.	34	33	11
R6 L12 17	T41-R16-W5	1970	14	12	23	0.0	0.0	26.1	mod. low	25	3.62	none	str. roll.	15	32	10
R6 L12 19	T41-R16-W5	1969	9	9	17	0.0	0.0	29.4	mod. low	62	3.93	none	undulating	17	26	10
R9 L18 1	T34-R9-W5	1970	39	19	38	10.5	2.6	5.3	high	41	2.18	scarified	gen. roll.	48	42	74
R9 L18 2	T34-R9-W5	1969	44	30	60	1.7	5.0	80.0	mod. high	49	2.02	scar&burn	mod. roll.	31	21	28
R9 L18 3	T34-R9-W5	1970	47	31	62	9.7	1.6	38.7	mod. high	106	2.02	scar&burn	mod. roll.	33	25	25
R9 L18 4	T34-R9-W5	1970	45	34	68	10.3	2.9	52.9	mod. high	66	2.20	scar&burn	gen. roll.	30	29	31
R9 L18 5	T34-R9-W5	1971	23	15	30	0.0	6.7	0.0	high	28	2.79	scar&burn	undulating	38	50	49
R9 L18 6	T34-R9-W5	1972	19	17	34	2.9	29.4	8.8	mod. high	35	3.95	scarified	mod. roll.	32	16	20
R9 L26 2	T34-R9-W5	1972	35	27	54	7.4	7.4	9.3	mod. high	18	2.40	scarified	undulating	30	32	41
R2 L14 1A	T41-R15-W5	1972	23	21	41	0.0	4.9	0.0	mod. high	34	3.02	none	gen. roll.	39	31	19
R2 L14 1	T41-R15-W5	1972	32	28	55	3.6	5.4	0.0	mod. high	16	2.53	none	gen. roll.	36	25	18
R2 L14 3	T41-R15-W5	1968	33	18	35	8.6	5.7	2.9	mod. low	25	2.51	none	mod. roll.	57	33	74
R2 L14 5	T41-R15-W5	1968	36	19	38	2.6	5.3	2.6	mod. low	14	2.65	none	mod. roll.	48	47	72
R2 L14 43	T42-R15-W5	1969	22	17	34	14.7	2.9	2.9	low	11	4.89	none	str. roll.	48	29	53
R2 L14 45	T42-R15-W5	1969	24	17	33	9.1	3.0	0.0	low	16	2.98	none	mod. roll.	51	37	37
R2 L14 53	T41-R15-W5	1972	31	24	48	6.3	2.1	0.0	mod. low	17	2.91	scarified	gen. roll.	40	21	19
R2 L14 58	T41-R15-W5	1972	22	17	33	9.1	6.1	6.1	mod. low	14	3.13	scarified	str. roll.	54	45	37
R4 L20 5	T47-R14-W5	1967	24	18	36	13.9	13.9	2.8	mod. low	152	2.63	scarified	gen. roll.	34	42	68

APPENDIX 2: Information and Data Summary for Clearcut Blocks Surveyed

Cutblock Designation	Legal Description	Year Cut Completed	Acreage Surveyed	Number PLots		Stocking %			Harassment Category	Dispersion Index	Edge/ Unit Area	Site Treatment	Topography	Vegetation Density %		
				Range	Pellet Group	Moose	Deer	Elk						Forbs	Grasses	Shrubs
G7 L1A 1	T62-R5-W6	1971	59	33	65	1.5	4.6	0.0	high	68	1.49	scarified	gen. roll.	39	21	20
G7 L1A 2	T62-R5-W6	1969	62	36	72	2.8	0.0	0.0	high	29	1.69	none	gen. roll.	38	20	16
G7 L1A 5	T62-R5-W6	1969	33	24	48	2.1	0.0	0.0	high	2	2.09	scarified	gen. roll.	30	17	27
G7 L1A 6	T62-R5-W6	1972	35	24	48	0.0	2.1	0.0	mod. high	9	2.19	scarified	mod. roll.	28	18	16
G7 L1A 7	T62-R5-W6	1969	58	36	72	2.8	0.0	0.0	mod. high	9	1.72	none	undulating	17	20	21
G7 L1A 10	T62-R5-W6	1970	69	36	72	1.4	5.6	0.0	high	4	1.51	scarified	mod. roll.	28	20	19
G7 L1A 13	T62-R5-W6	1971	28	23	46	6.5	0.0	0.0	mod. high	11	2.63	scarified	undulating	21	12	25
G5 S11 3	T64-R26-W5	1972	40	34	67	10.4	3.0	0.0	low	160	2.74	none	mod. roll.	50	36	32
G5 S11 16	T64-R27-W5	1971	52	30	59	6.8	0.0	0.0	mod. low	56	1.81	none	mod. roll	52	36	72
G5 S11 19	T64-R26-W5	1974	34	27	54	9.3	5.6	0.0	low	2	2.12	none	mod. roll.	49	26	37
G5 S11 24	T64-R26-W5	1972	28	23	45	4.4	6.7	0.0	mod. low	5	2.31	none	mod. roll.	49	17	31
G5 S11 26	T64-R26-W5	1972	41	30	59	5.1	0.0	0.0	mod. low	12	2.14	none	mod. roll.	44	28	25
G5 S11 28	T64-R26-W5	1972	66	39	77	5.2	1.3	0.0	mod. low	23	2.07	none	str. roll.	42	33	63
G5 S11 36	T64-R26-W5	1973	34	20	39	2.6	0.0	0.0	high	114	3.04	none	gen. roll.	34	18	23
G5 S11 37	T64-R26-W5	1973	28	19	38	5.3	2.6	0.0	mod. high	94	2.69	none	undulating	34	31	39

APPENDIX 2 (cont): Information and Data Summary for Clearcut Blocks Surveyed